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THE MATCH INDUSTRY

A KAFFIR GETTING A LIGHT WITH A FIRE DRILL

Frontispiece

(14581)

PITMAN'S COMMON COMMODITIES AND INDUSTRIES

THE MATCH INDUSTRY

ITS ORIGIN AND DEVELOPMENT

BY

WILLIAM HEPWORTH DIXON

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PREFACE

It is not intended that the reading of this little book should give sufficient information to enable anyone to begin the manufacture of matches; as that would be an impossibility in a work of so small a description as this one is; but it is hoped that it will be sufficient to enable the average reader, thirsting for information as to the methods adopted to provide an article of everyday use, to get at least an outline of its preparation and of the difficulties that have beset its path from the earliest times down to the present day.

In describing the gradual progress in the installation of the newest machines, it is not to be assumed that all factories have developed on the same lines, though a very great similarity exists amongst them all; but the outline given more especially applies to our own country, with which the author is more intimately acquainted.

In conclusion, my thanks are due to Messrs. Bryant and May, Ltd., for their assistance with information and photographs, which have been placed without stint at my disposal, as well as to the Gerh. Arehns Manufacturing Co., Ltd., of Stockholm, Sweden, and also to Messrs. Follows & Bate, Ltd., of Gorton, Manchester, and Messrs. Chambon, Ltd., London.

The Author.

11th *Jan.*, 1925.

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THE MATCH INDUSTRY

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THE production of fire has been one of the problems which have assailed man from the very remotest ages, and it is astounding to think that not until the early part of the last century and the study of chemistry, have any ready and easy means been to hand for producing it.

Chemistry and mechanics combined have at last taught us how to obtain what, to ancient civilizations, was a difficult and, in some climates, almost an impossible matter.

Of the origin of fire we can only conjecture; what agencies combined to produce it first hand we cannot even utter a guess; to find this out would provide a fine thesis for the modern scientific mind and plenty of food for reflection and, possibly, experiment.

It is not difficult for us to assume that at one period of the earth's existence it was one mass of incandescent materials of an inconceivable and immeasurable temperature, but the starting-point is beyond our conception. Radio-active elements of which we hear so much at

present may have constituted the starting-point, but whatever it was, the mystery of it remains unsolved.

Spontaneous combustion, of which many instances may be given, is known and has been for generations.

One of the commonest forms is the heating of the manure heap, another form the ignition of cotton-waste saturated with oil and the exposure of it to the air.

More modern examples may be cited in the well-known action of pyrophoric metals, and the spontaneous ignition of yellow phosphorus.

Whether the "Will-o'-the-wisp" is a similar case or not must be left to the imagination of the reader, as sufficient reliable information cannot be obtained as to its cause to be able definitely to lay down any dogmatic assertion.

The Latin name for this almost mysterious appearance of light, "Ignis Fatuus" (Ignis—light, Fatuus—foolish), is an indication of its nature, but it has so rarely been observed by scientific men that complete explanation of the cause of its appearance and nature can scarcely be attempted.

It occurs in marshy places in the evenings of the autumn, and its presence has been verified in various countries, such as North Germany, Italy, South and North England and the West of Scotland.

The light produced by this peculiar phenomenon has been described in various colours, ranging from blue to red and from green to yellow, but never pure white; sometimes remaining close to the ground, and at others in motion, fantastically jumping rapidly over the country, and rising high in the air, dividing itself into smaller flames.

Who has not read from time to time of travellers at night being misled and lost through its agency, mistaking its alluring light for a neighbouring cottage?

Common marsh gas has been given the credit for the "Will-o'-the-wisp," but this gas not being spontaneously inflammable must be ruled out, and the more probable notion accepted, viz. that it is due to phosphorescent vapour accruing from decaying vegetable matter ; its occurrence nowadays owing to the draining of the fens, is not so frequent, but that it has had and still has existence there is not a shadow of a doubt.

"Saint Elmo's Fire" is a case of another natural light production, though this time not of a mysterious character, as the cause is definitely known and leaves no room for discussion.

Its origin is electrical, and it is often seen during thunderstorms at the peaks of the masts of ships and spires of buildings.

"Greek Fire" is another substance to which the property of spontaneous combustion has been ascribed.

Invented by Callinicus of Heliopolis, in the reign of Constantine III, A.D. 670, it was used with great effect against the fleet of the Saracens.

The secret of its manufacture is now lost, but its chief ingredients are supposed to have been naphtha, pitch and sulphur.

It is stated by some writers to have spontaneously ignited when exposed to air ; though from its composition this would appear to have been without foundation. Whether the Greeks at this period were acquainted with the properties of yellow phosphorus is questionable, but that in order to produce results as related a certain quantity would have been necessary goes without saying.

Nowadays, we are able to ascribe nearly all these cases to oxidation, but to ancient civilizations, to whom the term was unknown, there naturally always existed a mystery.

It is, therefore, interesting to take a retrospective

glance at the very earliest times and so discern, if possible, the nature of fire as it appeared to them.

It is evident that the mystery of fire was so great that its deification became common.

According to Greek mythology, Prometheus was the means of obtaining fire from the chariot of the sun; possessed of inordinate cunning he outwitted even Jupiter himself, being assisted in his theft by Minerva.

The Romans kept fires continually burning by the aid of the vestal virgins, who dedicated themselves to the service of Vesta, the goddess of fire; they were severely punished if ever the fire became extinct.

At times this would seem to have occurred, for it is recorded that the fire was rekindled by the agency of the sun-glass, a method of obtaining fire too well known to need description, probably for this reason, it was supposed, that fire originated in the sun.

There is scarcely a primitive mythology which does not possess a fable about its origin.

A Celtic heathen festival to which the name of "Beltane" was given is another instance of the respect in which fire was held.

The word "Beltane" is derived from two roots, viz. "Teine" meaning "Fire," and "Beal," a Celtic deity.

This festival was generally held in May and November, the beginning and the end of summer.

All fires at these times were extinguished, and a "need" fire was then rekindled with great solemnity, and all domestic hearths re-started from this source.

That the "need" fire was looked upon as a purifying agent is known from the fact that men and cattle passing between two of them, and remaining intact, were reputed to be cleansed.

A practice of this sort still exists in some remote parts of Ireland.

It may be said, therefore, that fire, before its nature was fully understood, was personified and worshipped as were most manifestations of incomprehensible natural forces.

The Persians and modern Parsees who were followers of "Zoroaster," were worshippers of fire, and here exists a case in which the origin was ascribed to heaven.

Zoroaster having been credited by his followers as having brought their sacred fire down from that region.

Like the fire of the "Vestal Virgins," this is kept continually burning in holy places, being fed with choice wood and spices.

Amongst the Romans, Hindus, Slavs, and even Red Indians, "Fire Gods" were innumerable, some possessing all the virtues and others all the vices.

Fire was able to dispel the demons of darkness.

Trial by fire, or the "ordeal," was practised amongst the early Saxons, in which it was again a purifier which could not hurt the innocent.

It is probable that the only time the modern man would be found to be worshipping fire would be in the event of his inability to procure a match, and in this case his language might be somewhat unorthodox.

Another instance of the importance attached to fire is the interpretation of oracles by its means and, indeed, countless cases in which the sanctity of fire was recognized could be cited.

The constitution and nature of fire appears to have puzzled chemists of fairly recent times.

G. E. Stahl (1660–1734), a German chemist, supported and advanced what was then known as the "Phlogiston" theory—a word derived from the Greek "Phlogizo" (I kindle).

Stahl held that all combustible bodies were compounds

and must contain two constituents, one of which escapes during combustion and the other remains.

Bodies which would not burn, had lost their "Phlogiston." Needless to say this theory is now completely exploded, and the combustion of bodies is now fully and completely understood, the term combustion being commonly applied to those chemical processes accompanied by the evolution of light and heat through oxidation.

The most familiar of such are those in which the oxygen of the air combines chemically with what are generally given the name of combustible bodies, such as wood, coal, fats, oils, etc.

The oxidizing agent is, however, not always derived from the air, but can be some substance containing oxygen, such as Chlorate of Potash, which is the most usual, and which constitutes a very large proportion of all match compositions.

But we must hasten on and try to direct our attention to the manner in which fire, which in one way or another must always have been a necessity, was procured.

One method has already been stated apart from spontaneous combustion, viz. that of the "sun-glass," the method in the application of which is so well known to every schoolboy that it need not be described heie.

Amongst savage tribes other means were adopted for the purpose, most of which were by friction, and to this extent can be regarded as the forerunners of our modern match.

Instances of authenticated methods can be given.

The "stick and groove" fire producer was, perhaps, one of the earliest of these; two pieces of stick, one of which was shaped into a blunt point, was forcibly rubbed upon another flat piece lying on the ground until a channel was made. The natives of Tahiti adopt this

apparatus and are reputed to be able to obtain fire in a few seconds.

Captain Cook, in his voyages to Australia, tells us that the natives there adopted the "fire drill." He says: "They take two pieces of dry, soft wood, one is a stick about 8 or 9 in. long; the other piece is flat. The stick they shape into an obtuse point at one end; then,

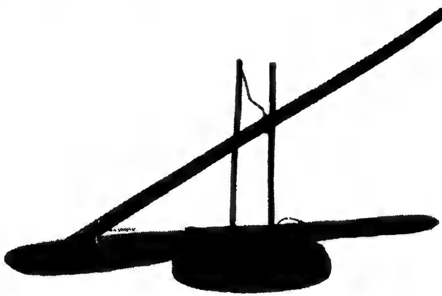


FIG. 1

STICK AND GROOVE

pressing it upon the other, turn it nimbly by holding it between both their hands."

The South American Gauchos used an instrument made after the style of a carpenter's brace.

Eskimos, to whom the production of heat and fire must have been all important, wound a cord round a drill, and pulling alternately at the two ends, caused it to revolve rapidly.

Sioux Indians used the "bow drill," in which the loose cord of the bow replaces the simple cord.

It is therefore evident that a variety of means, some primitive, others more or less mechanically ingenious, were in use.

The early Britons were probably acquainted with the

friction method of creating fire by means of two pieces of wood.

The friction of two sticks together was not, however, the only process known to the savage, for it is recorded that the natives of Tierra del Fuego were acquainted with the fact that by striking a piece of pyrites, with flint, sparks were evolved.

These sparks they caused to fall upon a piece of tinder, which became ignited.

The Romans also provided themselves with fire somewhat after the same manner ; they took two stones between which they placed some decayed wood and sulphur, and by rubbing the stones together produced the desired result.

We now come to a stage of transition in which wood is replaced by iron, and we find our Saxon progenitors fully acquainted with the efficacy of flint and steel.

" Fyr stane " was the name given to any piece of flint or pyrites which they found suitable for the emission of sparks.

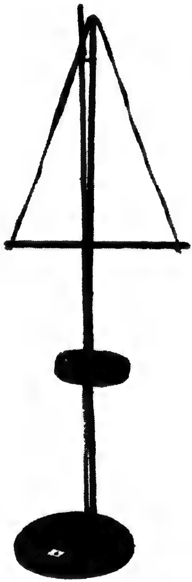


FIG. 2

FIRE DRILL

The more modern " tinder-box " which was used up to the early part of the last century, is nothing but a development of the Roman and Tierra del Fuego plans.

At the birth of flint and steel any odd bits of iron or steel were made use of, but these were gradually superseded by regularly formed pieces enclosed in a tin box to which was added a piece of tinder or charred linen.

The flint and steel having been brought sharply

together, the sparks thrown off were caused to fall into the tinder, when glowing took place.

As soon as this happened, a " spunk " or small piece of wood tipped with sulphur was held in the glowing

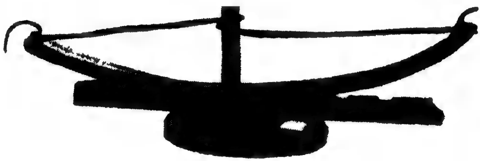


FIG. 3

BOW FIRE DRILL

FIG. 4

PRIMITIVE SAW FRICTION METHOD

tinder, when kindling of the sulphur and, finally, of the wood occurred.

From this it is evident that a further step forward has been made.

The provision of the " spunk " being in the nature of

an innovation, introduces us to the beginning of the easily inflammable match, and also to the chemical age of light producing.

Endeavours to effect a more easy and rapid method of creating inflammation were now numerous.

The more interesting ones will be described.

Mollet (a Frenchman), about 1807, was the inventor of an apparatus known as the "pneumatic tinder box."

This consisted of a hollow tube 4 or 5 in. long, into which a tightly fitting piston could be thrust.

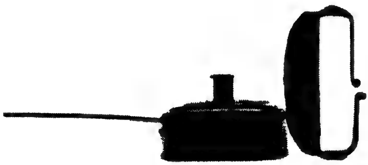


FIG. 5

TINDER-BOX AND STEEL

FIG. 6

FLINT AND STEEL FIRE PISTOL

On rapidly pushing the piston into the tube, compression of the enclosed air was effected, heat being produced.

After compression, the air was allowed to issue through very fine holes at the foot of the tube, and directed on to a species of tinder known as "Amadou."

"Amadou" was prepared by soaking thin slices of a vegetable fungus in a solution of nitrate of potash.

"Volta's inflammable air lamp" was designed to ignite hydrogen gas by means of an electric spark.

"Dobereiner's platinum lamp" (1823) was a fire producer of another description, and it consisted of a glass vessel containing hydrochloric or sulphuric acid; a piece of zinc plate attached to the lid and enclosed in

a glass bell could be introduced at will into the acid, hydrogen gas being produced.

The lid having been provided with a tap, the latter could be opened when the acid entered the glass bell containing the zinc, and the hydrogen was allowed to escape and impinge on a small piece of spongy platinum or iridium.

FIG 7

PNEUMATIC PUMP

FIG. 8

DOBEREINER'S LAMP

Ignition of the hydrogen through some obscure and only partially understood action taking place, which continued until the evolution of the gas caused by shutting the cock again and forcing the acid out of the bell by means of its own pressure when the reaction ceased and automatically commenced again the moment the cock was opened.

Yellow, or vitreous phosphorus, had been discovered by Brandt in the year 1673, although statements have been

made that the Arabs were acquainted with this body many years before.

Yellow phosphorus will ignite on coming into contact with air spontaneously, and ordinarily is stored under water.

It is therefore evident that if it could be controlled and this property made use of, it would be the much sought-after means of obtaining rapid ignition without any of the strenuous efforts previously enumerated.

The earliest attempt to effect this result was by gently rubbing small pieces between the folds of brown paper, and of bringing into the flame produced our wooden splint, or "spunk," tipped with sulphur.

If the object had been to severely burn the fingers, this method would have proved a brilliant success, but, owing to the prevalence of accidents this was discarded.

In 1781 came the "phosphoric taper"; in this case a piece of wick was coated with wax, and was enclosed in a glass tube, in one end of the latter was placed a small piece of yellow phosphorus, into which the wick dipped.

The glass tube being hermetically sealed, the *modus operandi* was as follows: The sealed tube was first warmed at the end where the phosphorus was situated, and the opposite end was cut off when the wick dipped with phosphorus was withdrawn, ignition taking place immediately.

Obtaining a mixture of phosphorus and oil was another of the various expedients essayed for making use of this element.

This mixture was put up into suitable vessels, and the old-fashioned "spunk" was immersed at the sulphur end into the mixture, ignition occurring by friction on a piece of cork.

Chancel, of Paris, in 1805, had introduced the

oxymuriate match. This is a different type of ignition to any up to now described.

In this, wooden splints tipped with a mixture of chlorate of potash, sugar and gum, were used ; the coated end was immersed in a small glass bottle containing sulphuric acid, evolution of an inflammable and explosive gas taking place.

Another type of the oxymuriate match was prepared and sold in this country under the name of "Jones's Promethians."

This consisted of a tiny glass tube about $\frac{1}{4}$ in. long, and about $\frac{1}{25}$ in. wide, filled with weak sulphuric acid, and this tube was inserted in the bottom of a spiral piece of paper furnished on the inside with composition of a similar character to that of Chancel.

FIG. 9
OXYMURIATE MATCH BOX

"Promethians" were sold in a tin box provided with two pairs of pliers, one to grip the spiral tube and the other wherewith to fracture the glass.

Ignition again took place on contact being established between the acid and the composition.

It has been stated that on occasions the fracture of the glass tube was effected by the teeth, this method could, however, not be recommended.

The non-success of this match will be apparent—spurting of the acid, burning of the fingers and clothing, being the natural consequences of its use.

Pyrophorus, already mentioned, now came for its trial.

Pyrophorus is a very finely divided metallic substance which takes fire immediately on coming into contact with air.

This material, previously prepared by heating Prussian blue in a glass tube, must be kept hermetically sealed; the method of use was by breaking the glass tube and allowing the contents to fall on to a piece of tinder or other easily inflammable material.

Chlorate of potash, which is to a very great extent contained in the modern match composition, was discovered by Berthollet, in 1786, and the use of this material for the supply of oxygen for the purpose of combustion was well known in the early part of the last century.

Hitherto, we have been dealing with igniting propositions in which the air has been the sole supporter of combustion. We have now, however, to begin to deal with a match tip, in which the combustible body and the supporter of combustion are mixed toegther and supply us with the idea for the advent of the modern fire generator—the match.

According to Webster's Complete Dictionary, the definition of the word match is given as follows: "A thing used for catching and retaining or communicating fire, made of some substance which takes fire readily, or which, on being lighted, remains burning a long time, especially in modern usage; a splint of wood dipped at one end in a preparation of phosphorus, sulphur, or the like, and ignited by rubbing."

The word match itself is probably derived from the Greek "*μύξα*." Latin, "Myxa," lamp-nozzle, lamp-wick.

The distinction of having produced the first friction match of this description belongs, undoubtedly, to an Englishman—John Walker—of Stockton-on-Tees, in 1827.

Walker was a druggist, and was much interested in chemistry.

He commenced by selling mixtures of chlorate of

potash and sulphide of antimony under the name of "Percussion powder."

From this attempt the idea occurred to him of attaching his powder to the end of a wooden splinter.

The adhesive used for this purpose was gum arabic, still largely employed in the safety match.

Walker's "Friction matches," the name under which they were known, were sold in tin boxes, provided with a piece of rough sandpaper.

Ignition took place on quickly withdrawing the wooden splinter with considerable pressure through the folded sandpaper; but, although these friction matches of Walker's were a considerable advance on anything produced up to this time, they were very far from perfect, and the disadvantages attending their use were numerous: the tips of the matches were easily detached under the force necessary to produce combustion, but they are undoubtedly the forerunners of the present strike-anywhere, as well as the safety match now so universally made use of.

In order to improve if possible the striking properties of Walker's match, a special friction was prepared consisting chiefly of chlorate of potash, but at the best they were unsatisfactory.

Walker's matches could not withstand the oncoming of yellow phosphorus, and were doomed, sooner or later, to extinction.

Various European countries lay claim to the successful embodiment of this material in the tip of a friction match, but it seems absolutely without question that on this occasion the honour is due to a Frenchman—Dr. Charles Sauria—of St. Lothair in the year 1831, and it is at this point that we are for the first time actually introduced to the first completely successful friction match.

By the use of yellow phosphorus a very great amount of rubbing to produce fire was unnecessary, and the drawbacks attributed to Walker's first friction matches disappeared for all time.

Glue, as an adhesive, into which yellow phosphorus had been emulsified, were the original ingredients for this match in Great Britain ; a very large proportion of yellow phosphorus being used.

Continual experiments were constantly made to reduce the amount, as phosphorus was exceedingly expensive.

"Congreves" was the name applied to the first matches of this character produced in this country. How the name came to be used in connection with it is not certain. Suffice it to say that the name is derived from Sir William Congreve, whose war rockets about this period obtained considerable notoriety throughout the whole of Europe.

It will not be necessary, and no particular object would be gained in traversing the innumerable attempts to reduce the amount of phosphorus consumed. It will be sufficient to say that chlorate of potash was a welcome agent in bringing about this desideratum.

From 1831 to 1898, yellow phosphorus matches continued to be manufactured and sold with very great satisfaction to the consumer.

Unfortunately, the use of yellow phosphorus was accompanied by a grave and very distressing disease called phosphorus necrosis, which defied almost every means attempted to eliminate it.

Phosphorus necrosis is a decay of the lower or upper jaw bone, due to the effect of the fumes of slowly oxidizing phosphorus entering through carious teeth

The introduction of machinery, and the resulting prevention of the handling of the matches, ameliorated

to a great extent this disease, but in spite of all care, the complaint persisted, and nearly all governments combined for the suppression of its use.

At the beginning of the present century, public opinion was much disturbed by the accounts of the distressing nature of the trouble, and, consequently, matchmakers began to conduct a large number of experiments for substituting some innocuous body which would give them a satisfactory result.

Amorphous phosphorus appeared to be the most likely thing, but the explosive character of this body when mixed with chlorate of potash was a serious deterrent.

Inventors were busy with all sorts of ideas for reducing the explosive character of this mixture.

In 1899, Akester proposed treating amorphous phosphorus with hot paraffin wax. The mixture consisted of 83 per cent of red or amorphous phosphorus, and 17 per cent of wax.

The only result of this was that the slowness of combustion had been accomplished so successfully as to almost prevent the possibility of getting any ignition whatsoever.

Other experimenters suggested a lead compound, easily decomposed and oxidized, viz. Thiosulphate of lead.

Thiosulphate of lead is not in itself sufficiently sensitive to friction for the purpose, and even if it had been it is extremely unlikely that match manufacturers could have been induced to adopt it, as they had no desire to substitute the poisonous effects of yellow phosphorus for that of lead.

It appeared to them, to use a common expression, "to be jumping out of the frying pan into the fire."

Another modification of phosphorus from which it

was hoped to obtain good results was "Schenk's phosphorus," and a patent for the use of this material was granted in 1902 to Messrs. Muir and C. R. E. Bell.

This second modification was discovered by Schenk and, if anything, is a little more active than the amorphous variety, but as a competitor to the sesqui-sulphide of phosphorus it had but a short life, and has now entirely disappeared from all match compositions.

Dr. Wheelwright suggested hydrides of phosphorus in 1902.

A large German chemical manufacturing company proposed the use of a suboxide of phosphorus, but it is open to serious question whether this oxide actually exists.

The same company also suggested a material which they designated "Sulfophosphit," a mixture containing phosphorus, sulphur, and very finely divided metallic zinc.

Craveri, an Italian inventor, suggested a very inflammable body known as persulphocyanic acid in combination with cyanogen persulphide, nitronaphthalene and chlorate of potash.

As a match composition containing neither phosphorus itself, nor any of its compounds, it came as near to success as anything tried up to this period; it had, however, very many disadvantages and drawbacks.

Persulphocyanic acid is an exceedingly light body, and the dust of it is difficult of control; it permeates the air with the greatest ease, filling the mouth with a particularly objectionable taste, and irritating the eyes to a serious extent; besides these objections there existed the question of the poisonous nature of any compound of cyanogen, claiming a kinship with prussic acid, the nature of which is known to most people.

These objections, as well as the uncertainty of ignition,

mitigated against its adoption, and it was of course rejected.

In 1901 Bale attempted to continue the use of ordinary yellow phosphorus by forming a compound with naphthalene, to which he gave the name of naphthalene phosphide.

Bale assumed that his compound was of a non-poisonous nature, and he based his assumption on the fact that naphthalene itself was an antidote to necrosis.

It was difficult to give credence to this questionable assertion; in fact, to maintain the contrary, was much easier, and seeing that phosphorus fumes continued to be given off by his naphthalene preparation, it was only possible to get assurance of its non-toxic properties by a prolonged trial during which more cases of necrosis might have occurred.

Consequently, it did not take the manufacturer very long to dismiss the proposal from his mind, and to adopt something by which he was free from any fear of deleterious results, and this he found in sesqui-sulphide of phosphorus.

In the year 1898, Messrs. Sevène and Cahen, two chemists in the employ of the French government, took out a patent for the use of this compound for the preparation of compositions in the manufacture of strike-anywhere matches.

Phosphorus sesqui-sulphide was first prepared by G. Lemoine, in 1864, and it would at the present time appear strange that in spite of the ravages of necrosis, the usefulness of this material was not appreciated until so late a period.

The first users and patentees in Great Britain were Messrs. Bryant and May, Ltd., at whose factory the author of this book had the gratification of carrying its use into practice.

Licences were granted to all other makers, and so the insidious effects of a poisonous body were, to the relief and satisfaction of all concerned, manufacturers and users equally, eliminated, and match-making has become one of the healthiest occupations in existence.

A few words before finally bringing our first chapter to a close, must be written on the history of the safety match, as these are manufactured on a somewhat different principle.

The tip, or igniting portion of the match, does not contain any combustible very easily ignited by friction. Its constituents are, principally, chlorate of potash, sulphur, gum and glue, whilst the specially prepared surface consists of amorphous phosphorus, antimony sulphide, and other non-important ingredients; gum arabic again being the adhesive.

Amorphous phosphorus, discovered by von Schrötter in 1845, is a modified form of its ally, the yellow variety.

It is nontoxic; it does not fume or take fire in air, and possesses entirely different properties.

In the preparation of the safety match the two materials, viz. the combustible body and the oxidizing agent are kept asunder; the former being on the box, and the latter on the tip of the match, the bringing together of the two being the means of inducing ignition.

The first matches of this description were made in 1855 by Lundström in Sweden.

Lundström's patent was purchased in the same year by F. May, of Messrs. Bryant and May, and since this time a constantly increasing manufacture and use has occurred in practically every country in the world.

It can be asked why it was that, after the birth of the safety match, yellow phosphorus matches were not immediately proscribed.

Conservatism, prejudice, as also the convenience and

excellent striking properties characteristic of the yellow phosphorus match combined to force a continuation of its application, until it was replaced by the sesquisulphide of that element from which at the present moment all strike-anywhere matches are manufactured.

In recent times there has been a recrudescence of the principle of the old tinder box in, however, an improved though by no means an efficient, type; and in order to complete the historical account of the evolution of light and heat producing methods a short explanation is necessary.

Auer von Welsbach, a Viennese, a name well known from its association with gas mantles, observed, during experiments he made with some of the rare metals which are embodied in the gas mantle, that some of them had the property of giving off, very copiously, inflammable particles when rubbed against a hard substance.

This property, he found, was much increased when the metal cerium was incorporated with about 30 per cent of iron. Fire producers of various patterns have been put upon the market embodying this principle; the emitted sparks being directed by a suitable mechanism on to a cotton wick saturated with petrol or other easily burning liquid.

The disagreeableness of carrying petrol in the pocket as well as the uncertainty of ignition has mitigated against the adoption, on any large scale, of these modern tinder-boxes, and they offer a very limited opposition to the clean, cheap, and always reliable match.

One of the dreams of the modern matchmaker in very recent times is, to produce a headless match, and various patents, having this object in view, have been taken out.

If this idea could be accomplished it is easy to see that the cost of production ought to be reduced considerably,

as the operations of applying the paraffin and the tip, and the drying would be superfluous, resulting in the elimination of expensive machinery and a vast amount of labour.

The method employed generally takes the form of soaking the splint in some compound easily yielding up its oxygen.

Another advantage accruing therefrom consists in obtaining a quantity of matches occupying a much reduced space and the resulting possibility of minimizing the dimensions of the box required to hold the matches.

Probably the earliest effort to endeavour to succeed with this problem was made by B. Schwarz, in 1889, and the translation of his original document reads as follows: "The subject of the present invention is a match which, unlike those now in use, has no dip.

"The ends, however, are impregnated with the following solution—

20	parts by weight of	chlorate of soda
4	,,	sulphate of ammonia
2	,,	sugar or gum
30	,,	water

"The matches do not require, as hitherto, to be put into frames, it is sufficient if the bundles of wooden splints be dipped in the solution and then left to dry."

Variations of the above have from time to time been made but have not met with success.

In 1900, Dr. Harwood Huntingdon, of New York, proposed saturating the splints in a solution of chlorate of potash and antimoniate of potash, or, alternately chlorate of potash and barium hydrate or, again, chlorate of potash and ferrocyanide of potash.

One of the most recent attempts in this direction is described in a patent specification granted to a Japanese in 1921.

In this specification the splint is first soaked in " vacuo " in a solution of sodium chlorate and dried ; finally being dipped on the tip in a solution of barium chlorate and dextrine.

In this case it will be observed there are two impregnations, one of which saturates the splint throughout its total length, and the other on the tip of the splint for initial ignition.

The intention of all these suggestions is to make use of the wood of the splint as the combustible body, and

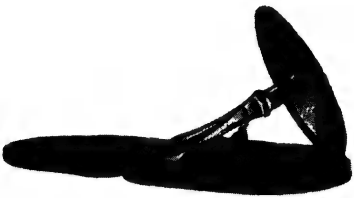


FIG. 10

ELECTRIC FIRE PRODUCER

by the absorption of the oxidizing agent by the wood to complete the match.

Naturally, these matches would require the use of a special friction surface, similar to that provided for the ordinary safety match.

As to whether this principle will ever be brought to fruition must be left to the future, but, so far, ignition of these matches has been too uncertain for their adoption by any manufacturer who prizes quality, and desires above all other matters to give satisfaction to the public. .

Summarizing all the foregoing remarks it can be stated that friction has been the favourite agency for obtaining fire, and it is superfluous to remark still continues in use in all modern methods for accomplishing that object.

CHAPTER II

MATERIALS ; THEIR USES AND MANIPULATION

RAW materials for safety and strike-anywhere match, and for safety friction paint—Methods of mixing—Specimen compositions.

To attempt a description or to give an account of every substance that has been made use of in the manufacture of matches, would occupy too much space, and, as a large number of them have been tried and discarded owing to the unsuitability in one way or another, it will be sufficient to enumerate and give a short statement concerning those in actual use at the present moment, both for strike-anywhere and safety. They are the following—

Sesqui-sulphide of phosphorus (strike-anywhere).
Oxide of zinc (strike-anywhere).
Ground glass powder (strike-anywhere and safety).
Asbestos powder (strike anywhere).
Plaster of Paris (strike-anywhere).
Chlorate of potash (strike-anywhere and safety).
Glue (strike-anywhere and safety).
Gum arabic (safety).
Sulphur (safety).
Manganese-dioxide (safety).
Oxide of iron (safety).
Infusorial earth (safety).
Bichromate of potash (safety).
Amorphous phosphorus (safety friction).
Sulphide of antimony (safety friction).
Paraffin wax (strike-anywhere and safety).
Wood (strike-anywhere and safety).

Stearine (wax vestas).
Gum dammar (wax vestas).
Cotton (wax vestas).

It will be evident on looking through this list that there are some ingredients in it that have apparently no influence on the production of light, and take no active participation in the combustion.

Of what service then are glass powder, asbestos powder, plaster of Paris, and oxide of zinc applied to the preparation of the strike-anywhere match paste; or of dioxide of manganese, oxide of iron, infusorial earth, bichromate of potash, to the safety match?

The explanation is simple: They are all used as fillers, with one or two exceptions, and they serve to modify the violence of the reaction on ignition.

They serve to separate and to keep apart those active parts of the mixtures which, otherwise being in too close proximity to one another, would result in an explosive combustion not to be tolerated. In other words, they are diluents, and this purpose is served by their admixture.

A short description of the properties of each one will now be given—

Sesqui-sulphide of Phosphorus. Chemical formula, $P_4 S_3$, and as its formula shows, consists of four parts of phosphorus chemically combined with three parts of sulphur.

It was discovered by G. Lemoine in the year 1864, by heating the two elements together in the absence of air up to a temperature of 260° centigrade.

After the reaction of combination is ended, a solution of the product is obtained in carbon-bisulphide, from which it is recrystallized and obtained in a pure state.

It is a yellow crystalline solid; burns readily in air; forming oxidation products of its constituents, it can

easily be handled and transported, but unlike yellow phosphorus it does not take fire in air, but only very slowly decomposes ; it does not give off noxious fumes.

Mixed with chlorate of potash in the dry state it is explosive, and for this reason precautions of an elementary character must be taken.

It has entirely replaced the use of yellow phosphorus and is non-toxic ; and although it does not produce a match so ready of ignition as the latter, nevertheless is instrumental in permitting the manufacture of one which is good enough for all practical purposes and with which consumers are more than satisfied.

Oxide of zinc. Chemical formula, $Zn\ O$.

This combination of zinc and oxygen occurs in nature as zincite or red zinc ore.

For the preparation of match pastes the native product is not used, but the oxide known in commerce as zinc white.

This is prepared on a large scale by the distillation of the metal itself or by roasting the carbonate.

Its use in the composition is fourfold. It is a filler, it prevents interaction between the chlorate of potash and the combustible body—sesqui-sulphide of phosphorus—and in addition imparts a smoothness and consistency not obtained by any other material and, finally, improves the gelatinizing point of the glue.

Some strong glues, white in colour, and sold as " Russian glue," are made to contain this body.

Its use dates from the introduction of Sevène and Cahen's match in large quantities.

It has a peculiar property of being a yellow colour when hot, becoming white again on cooling, an attribute which can sometimes be observed by looking closely at a match tip, immediately after it has been extinguished.

Glass powder. Little or almost no description of this common substance is wanted.

It is simply used as a cheap diluent and, possibly, to increase the friction effect.

Old bottles and other glass refuse are used in its making, and therefore consists chiefly of silica, for which the formula would be $Si\ O_2$.

Asbestos powder. This is not altogether, as its name would seem to imply, simply asbestos fibre finely ground, but is a mixture of the silicates of magnesium and aluminium, and is of a somewhat complicated chemical formula.

It more closely resembles steatite or kaolin or china clay.

It is an inert compound, not easily decomposed, and remains unchanged during the combustion of the match.

Its specific gravity, which is low is, to a great extent, its recommendation, as the use of too great a proportion of heavy diluents causes settling out of the composition.

It therefore supplements ground glass, which is exceedingly heavy and cannot be used too abundantly.

Plaster of Paris. Chemical formula $Ca\ SO_4$.

It is therefore a sulphate of lime, and is prepared by roasting gypsum. The latter is found in nature consolidated with considerable quantities of water.

Chemically, gypsum is a hydrated sulphate, and the plaster of Paris is prepared therefrom by roasting the native product up to 120° centigrade.

When water is again added to the roasted gypsum, a combination occurs and solidification into a hard mass. It is this latter characteristic which appeals to the matchmaker, as by this means a quicker setting is obtained and boxing can take place earlier.

As in the case of ground glass and asbestos, plaster of Paris is also a filler.

Chlorate of potash. Chemical formula $K\ Cl\ O_3$.

A most important and interesting ingredient of match tips.

When chlorate of potash is heated, evolution of oxygen takes place in large quantities, this outstanding property is the one on which the success of the match depends.

It would be almost an impossibility to evolve a satisfactory ignitive dip without its assistance.

There is no other agent of oxydation from which such results can be obtained as from this material.

The original supply of the raw potash was extracted from burnt seaweed or "kelp," but the deposits of Stassfurt have entirely supplanted this method.

During the Great War, owing to the difficulty of obtaining the natural deposits, recourse was had again to the early method of its preparation, and for some time the feasibility of producing matches in quantity in this country hung in the balance.

Electricity has, finally, come to the aid of the chlorate of potash manufacturer, and has considerably simplified its production, which is of wonderful purity. Commercially, it contains not more than ·1 per cent of impurities.

Glue. An organic compound consisting of a mixture of many different combinations, the formula for which it is not possible to give with any degree of accuracy.

Of all the materials at present in use in the industry, glue is the one which gives the manufacturer the greatest amount of anxiety.

A first-class and carefully prepared hide glue is an absolute necessity if the match producer wishes his plant to run smoothly throughout the year and to make sure of his quality.

An outline of the means of obtaining glue will suffice

for the present purpose, and it will not be possible to enter into the details as space forbids.

Pieces of hide, known as "fleshings" in the trade, are taken and cleaned of blood, etc., by treatment with lime; the lime having been washed out with slightly acidified water and, finally, with water alone; the cleansed "fleshings" are then subjected to boiling in a cauldron by steam.

The glue collects at the surface and, as required, is skimmed off, and whilst in a liquid state placed in moulds and allowed to dry.

The qualities which a matchmaker's glue must possess are: high viscosity, high melting point, quick setting and drying properties and good jelly strength. Each one of them we will consider seriatim—

High viscosity. Mention has already been made of the desirability of preventing settling out of the composition by using materials of a light specific gravity, but the great factor in maintaining a state of homogeneous suspension is the viscosity of the glue.

If, for instance, the heavy materials fall to the bottom of a batch of match paste, it will be obvious that the completion of a reliable match would be out of the question.

Viscosity is another name for stickiness, and, the more viscous the glue solution is, the less likelihood is there of any separation of the ingredients.

To illustrate the contention: let us suppose that a thin glue is being used and that the chlorate of potash, with other heavy materials, has settled down and finds its way to the bottom of the container, there would in this case be no vitality in the upper portion to give ignition, whilst the nether portion would probably be explosive when dry. For this reason a really sticky or highly viscous glue is absolutely essential.

High-melting point and quick-setting properties are somewhat synonymous terms and are therefore difficult to differentiate. Generally speaking, if a glue has a high-melting point the second part follows.

The object of the manufacturer, as soon as the splint has received its quantum of composition, is to arrive with the least possible delay at a state in which the matches can be placed in the boxes without damaging the tips.

Obviously, then, if this condition is to be quickly effected, a glue which remained in a liquid condition for a long time would prevent the desired result from being accomplished, and retard the whole work of the factory from beginning to end, and seriously interfere with the daily production, and greatly increase the prime cost.

Further, the formation of badly-shaped heads is a corollary incident to slow setting, giving rise as it would to an elongated tip with an accompanying tendency of the mixture to drip off the splint.

During specially hot summer weather it is sometimes very difficult to continue to run the factory from this cause, and specially strong glues are for that reason brought into requisition.

Again, if use is made of slow-setting glues, the matches will continue to keep in a sticky condition at the moment they come to be boxed and would be found all cleaving together when presented for acceptance to the consumer.

Settling out such as comes to pass in the batch and against which the viscosity of the glue is provided, can occur even on the small tip of the match.

But the chances are distinctly against this if the glue grips the ingredients as soon as they are applied.

Assuming for the purpose of explanation that a poor glue has been used, it may and does happen when

atmospheric conditions are favourable, that the length of time taken for the match to become firm has resulted in a partial disjunction of the materials of which the match composition is created, and the following outline will serve to explain how this is brought about and the consequences—

A is the splint ; B and C the tip ; C, shown as a dark rim round the outside of the head, is a coating of impervious glue, dry and hard on the surface, and contains only moderate proportions of the combustible body and its accompanying oxidizing agent, the two latter having accumulated in B.

B, therefore, contains considerably more than its share of the vital constituents, resulting in fierce inflammation.

If now the match be struck at, say, point D, firing takes place directly the hard outer skin has been worn off, and penetration into B develops and combustion is very violent and is confined within B.

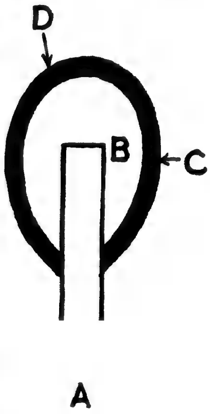


Fig. 11

When a match has been turned out as it should be, the gases produced on ignition can readily find an outlet over the total superficial area of the head, but in the case under discussion, it would be impossible, owing to the impenetrable skin having been formed, and, consequently, there are miniature explosions, pieces of the head being thrown off and giving rise to what are, amongst the employees, commonly designated " sneezy matches."

Needless to say, constant attention is given to this point during any weather where the temperature is above

the average in the summer and the glue does not set in the usual quick time.

It will, therefore, have been made clear why the setting properties of the glue are such an important necessity.

Naturally, the speed at which a glue will set or gelatinize, depends to a very great extent on the temperature of the room in which the dipping is being done, and also the proportion of water with which the glue has been brought into solution.

Both these points are incessantly receiving attention. The room is kept as cool as possible compatible with a good drying temperature, whilst the proportion of water is increased or diminished as atmospheric changes occur.

In some climates, where the air is surcharged with moisture and the temperature high, special and elaborate machinery has been installed for the regulation of the two points mentioned above.

Consequent upon the industry's becoming daily more scientific, the old "rule of thumb" methods are being driven out, and any manufacturer who has any claims to be "up to date" takes the precaution to have his glue all tested before being consumed, to make certain that it possesses the necessary qualifications for the purpose intended.

The question of a good drying glue, although not entirely dependent on the setting quality, is to some extent connected with it, but no pressure can be applied to dry quickly until the glue has set as otherwise the glue would remain in a liquid condition.

Jelly strength is the final, but by no means the least, important of the requisite characteristics associated with a good glue, and this does not depend upon the quantity of gelatine contained therein, but on the quality of the gelatine itself, which may vary to a great degree.

A glue, whose gelatine contents are 70 per cent, may

be, and often is, preferred to one of 90 per cent, it the latter quantity is of an indifferent nature.

The gelatinizing properties of a glue are very easily ruined even during its manufacture.

Too much heat applied during its formation and in the melting of it afterwards will bring about its ruin ; especially if the heat be direct. A water bath for bringing about its solution should therefore always be used for this purpose.

Glue heated up and allowed to cool a few times loses its setting properties and becomes useless.

A simple illustration of the way in which " jelly strength " is tested will show the full meaning of the term.

If a solution of glue of a stipulated strength in water is permitted to solidify in a convenient vessel (a beaker being the usual receptacle) and is cooled to a constant temperature, the surface will sustain considerable weight without fracture.

The point at which the rupture of the jelly occurs is its strength.

Jellies of weak glues easily give way under pressure. Strong glues not so.

In practice, and in the best establishments, a weak jelly will be at once rejected, as it is a foregone conclusion that the result of its use would be to interfere with the quality of the product and to give rise, under certain conditions, to explosive matches, as the binding strength is not sufficiently great to hold the particles together when the combustion of the match takes place.

Match glues, in consequence, must " set " and dry quickly, must possess a high melting point and a strong jelly.

Gum arabic. This is a natural product, again of a complicated organic structure ; it flows spontaneously from the branches and trunks of the " Acacia Arabica."

It hardens naturally on exposure to air, and is used in conjunction with glue in safety-match compositions.

It will not gelatinize.

Better safety matches can be prepared with a certain proportion of it, because of its more ready inflammability with an oxidizing agent.

It has to be borne in mind that the initial firing of a safety match springs from its friction on the prepared surface on the side of the box, and that of itself, unless subjected to extreme pressure and a sharp stroke on a smooth surface, cannot be ignited.

Gum arabic, therefore, to an extent replaces glue, but it is not left alone, it is chemically treated so as to thicken and partially set it, this being effected with bichromate of potash, the action of which will be given under that heading.

Sulphur. Chemical formula S.

This is found native in Sicily, Mexico, New Zealand, and many other countries.

Purified and sublimed it presents itself in the form of "flowers of sulphur," and is used in this form in a very fine state of division, providing the combustible body in the safety match, and can be regarded as the sesquisulphide of that match.

It is sometimes prepared from solutions, and is then sold as "precipitated sulphur," but is very rarely, if ever, used when produced from this source.

Oxide of iron. Chemical formula Fe_2O_3.

Very often called "caput mortuum," or *anglice* "dead head," a name adopted by the alchemists to denote a fixed residue after all volatile matters had been driven off by heat.

It is prepared in many ways, and is more or less a by-product of some other chemical preparation, such as the roasting of the sulphate of iron or of iron pyrites.

Its use in safety matches is in the nature of a filler and as a colouring matter.

Manganese-dioxide. Chemical formula $Mn\ O_2$.

This, again, is found in nature as "Pyrolusite."

From its native condition, it is subjected to very fine grinding.

Amongst chemists, this compound of manganese and oxygen is known as a "catalytic," from the Greek word, "kataluo," I dissolve.

Catalysis is a term applied to the peculiar action that is possessed by certain bodies over others, without themselves taking part in the chemical changes involved.

Thus, yeast converts sugar into carbonic acid and alcohol without entering into combination with either.

Ordinarily, chlorate of potash melts at 650° F., and gives off its oxygen at 700° F., but if mixed with about 25 per cent of its weight with this oxide, the evolution of the gaseous supporter of combustion commences at 450° F., the catalytic agent remaining unchanged.

Its usefulness will on that account therefore be obvious.

Infusorial earth. This is almost a pure silica, and as such should possess the formula $Si\ O_2$.

It is a peculiar and at the same time an interesting body, originating from a class of exceedingly minute animalculae, inhabiting stagnant water either fresh or salt, in which a plethora of decayed animal matter or vegetable is contained.

It is the siliceous shields of the "Diatomaceae," and is frequently called "Diatomite."

It is, further, an exceedingly light and bulky material, which is its chief recommendation.

Its low specific gravity aiding its capacity to remain suspended in the composition and preventing its separating out, as well as increasing the bulk and yield of matches.

It will absorb large quantities of water, in some

cases of the best quality as much as five times its own weight.

Bi-chromate of potash. Chemical formula $K_2 Cr_2 O_7$.

This is a useful article, which has a specific action on both gum and glue.

In both these two substances a thickening occurs on adding bichromate of potash to their solutions in the presence of light.

Both glue and gum are, more or less, rendered insoluble in water by its action, thereby preventing the absorption of moisture in the match tip, and giving it waterproof qualities.

Amorphous phosphorus. Chemical formula P.

A modified form of the yellow variety and has the same formula.

This is a case of "allotropism," a word derived from the Greek "Allotropos," i.e. capable of being turned from one thing to the other.

It is generally accepted that this body and yellow phosphorus are identical, the difference being solely in the arrangement of their atoms.

When burnt in air both yield the same products of combustion.

Yellow phosphorus is a waxy, semi-transparent body, and is so easily kindled that the heat of the hand is sufficient, and it must constantly be stored in water, whereas the amorphous variety is a dark brown infusible powder and can be exposed to the action of air without undergoing a change, except very slowly. It is, therefore, this property which gives it its usefulness for the friction surfaces of safety matches.

Unlike the yellow phosphorus it is non-poisonous, and does not emit noxious fumes.

Its explosive force when mixed with chlorate of potash is terrible, and the two things are kept severely

apart until the head of the match comes into contact with the box.

Sulphide of antimony. Chemical formula $Sb_2 S_3$.

This compound, it will be remembered, we have made an acquaintance with previously, as it was an important constituent of Walker's original "friction lights," but in that case was embodied in the match tip, a position it has now vacated to become a member of the friction composition.

"Stibnite" is the name given to it in nature, where it is found in a crystalline form, and from this condition it is changed by being finely ground before its availability can be recognized.

It is used as a modifier of the reaction between the chlorate of potash and amorphous phosphorus.

The use of the latter alone being prohibited, as the friction itself would continue to burn unless some diluent accompanied it.

Paraffin wax. The composition of this material is purely organic and somewhat complicated, and varies according to its melting point, which has considerable range.

It is prepared in great quantities by the distillation of shale from retorts.

It is easily inflammable in air, and has now almost entirely replaced the use of sulphur for the dipping of the splint, and for this purpose is much to be preferred, as it is easily absorbed by the hot splint and gives rise to no pungent smell when burning.

The distillation from shale is done in various fractions, and the melting point alters in accordance.

Usually a melting point of between 100° and 118° F. is preferred, but there is no fixed rule, some manufacturers liking a low and others a high temperature of liquefaction, depending on the climates for which the

match is designed, or the nature of the wood being treated.

If the wood is hard in character, a low melting point is more desirable, as it is more readily absorbed.

Its place on a match splint is as an intermediary inflammatory agency between that and the tip: without its assistance extinction would occur as soon as the composition had expended itself.

Wood. In Great Britain, two kinds of wood are made use of for cutting into splints, viz. aspen and pine. In most other countries, with the exception of the American continent, it is almost exclusively aspen.

Aspen arrives in great quantities from Russia and Finland, although it is a native of Great Britain.

Tremulous Poplar is a name applied to it, owing to the fact that the slightest breath of wind sends its leaves into a quivering motion, and " trembling like an aspen leaf " has become proverbial.

Its cultivation is possible in almost any soil, but preference is given to a moist and gravelly one.

Almost exclusively it is used now for the cutting of match splints, although other uses have been assigned to it, viz. for the shaping into arrows ; and an interesting fact in relation to it is that during the reign of Henry V of England an Act of Parliament was passed to proscribe its adaptation for any other purpose, the penalty being, for a breach of this regulation, 100 shillings, no small fine for that period.

Its scarcity in this country can therefore be perceived.

The Act was repealed by James I.

There is an old legend in connection with aspen, that it supplied the wood for the Cross, and that it has never ceased to tremble since.

Its adaptability for matches, however, does not depend on any of these interesting features, but accrues from

its being easily worked into veneer, is porous, is easily kindled, is of the correct colour, strong, and free from knots and cross-grains.

At the moment there is an abundant supply, but the forests of its source are being emptied rapidly, and the probability of its scarcity has received the attention of some manufacturers who have looked forward to such a contingency.

Messrs. Bryant and May, Ltd., have already made their preparations for a home-grown supply, and have acquired considerable tracts of land in Scotland, where aspen and other species of timber are being brought into cultivation, from which it is expected an ample supply for all future requirements will ultimately be forthcoming.

Pine, the other form of timber still largely used in this country, more especially for those matches known as "Swan Vestas," is imported from the Northern American continent.

Many varieties of pine are known to exist, most of which are unsuitable for matches, owing chiefly to their rosin contents.

The pine used is the white or deal of Canada and the United States.

Just as in the former case of aspen, the scarcity and ever increasing value of this timber gives rise to anxiety, and replanting arrangements, if its continued use is to be relied on, will sooner or later have to be proceeded with.

This tree grows to enormous proportions, a height of 150 ft. and diameter of 5 ft., having been found.

Unlike aspen, which is received in the shape of logs, pine is delivered in small blocks prepared ready for the feed of the match machine of the required size.

Stearine, or stearic acid (Chemical formula $C_{18}\,H_{36}\,O_2$) obtained by treating tallow with caustic potash and

subsequent neutralization with dilute acid, is an animal fat, and is used in the making of the wax vesta stem.

It melts about 130° F., and is as a general rule a pure white with a crystalline fracture, and is inflammable in air.

If uncontaminated with oleic acid, it will keep its colour almost any length of time.

Its firmness with cotton wick is its recommendation.

Gum dammar, or copal. Either of these two gums is used in the wax vesta stems. Both of them are soluble in melted stearine in large proportions.

They are not water soluble gums, and come therefore under a different category from the gum arabic already described, but they are both exudations from trees, and are allied to rosins.

Dammar is imported from Southern India. Copal from Africa, America and the East Indies.

Stearine loses its friability when mixed with either of these two gums, and is hardened.

Cotton. Cotton is almost entirely pure cellulose, and is the one and only fibre which is suitable for wax matches.

It is made up into reels at the mills, containing many threads, and is of very fair American-grown quality.

The fineness of the thread is an important item, and the finer the thread used the stronger the taper.

A count, or fineness, equal to 16's, is the general rule, finer counts, although better, being too expensive.

Preparation of compositions. The first step after having provided all the materials required for the mixing of the compositions is to get the glue of the convenient strength into a state of solution by warming on a waterbath.

Glue is first crushed, if not already delivered in that state from the maker, and placed in a receptacle, usually a cast-iron copper, capable of holding about 2 cwt. of the finished composition.

It is then allowed to stand a few hours, until it has absorbed as much water as it is capable, when, on being warmed, solution is easily effected without excessive heat.

When a solution of glue in water is obtained, if it is desired to prepare a strike-anywhere batch, the weighed-out quantity of sesqui-sulphide of phosphorus is added and thoroughly mixed mechanically with the glue, so as completely to saturate the former before adding the other ingredients, including the chlorate of potash.

This preliminary step precludes any possibility of mishap from explosions, as the sesqui-sulphide becomes by this means wet and practically incombustible and inert.

The remaining parts, such as the zinc oxide, ground glass, plaster of Paris, etc., are then added, continual mixing as before taking place.

The chlorate of potash is the final addition, and is wetted specially by a portion of the water required to complete, which has been reserved for this object.

After further agitation and the addition of a dye of the shade wanted, the whole is removed to a mixing mill, an illustration of which is shown.

The simplicity of the mixing is such that manipulation of the combustible material with the supporter of combustion has, since the inception of the sesqui-sulphide match, given rise to no accidents from explosion, and there is no single record of any untoward event as having occurred.

A is the hopper of the mill into which the composition to be ground is overturned. B, the driving pulley communicating motion to gears C and D. D is attached to a vertical spindle working into the bottom part of the mill, to which it imparts a revolving motion in the direction and against the scraper, which can be observed above the lip from where the composition issues after having traversed between two plates, one of which is

Mixing of the friction paint for the sides of safety boxes is mostly carried out in a different type of mill, as exceptionally fine and almost colloidal grinding is aimed at, so that a smooth and even surface appears.

In this instance, the use of a ball-mill is the most successful in turning out the result wished for.

This consists of a drum (as illustrated on p. 43) of thick cast-iron, set aslant, and the contents which are introduced or emptied out at the man-holes seen at the top and bottom, have imparted to them a rotary motion, whilst a number of balls of various circumferences are placed in the mill and revolve with it, but in the opposite direction to the way the mill itself is rotated.

A little reflection on examination of the drawing subtended will, no doubt, make its efficacy clear.

The following are some typical examples of match compositions—

(*a*) Walker's "friction lights" probably consisted of the following ingredients—

	lbs.	ozs.
Antimony sulphide	30	0
Chlorate of potash	28	0
Oxide of iron	5	5
Gum arabic	36	5
	100	0

(*b*) Yellow phosphoius strike-anywhere composition (now discarded)—

	lbs.	ozs.
Chlorate of potash	28	0
Carbonate of lime	12	0
Ground glass	12	0
Plaster of Paris	3	0
Yellow phosphorus	4	0
Glue .	17	0
Water .	24	0
	100	0

(*c*) A very early safety-match composition of 1864—

	lbs.	ozs.
Gum arabic .	4	
Glue . .	2	
Chlorate of potash	44	
Red lead . .	10	
Manganese dioxide.	10	
Black antimony sulphide	5	
Water . .	25	
	100	0

(*d*) A safety-match composition of the present day—

	lbs.	ozs.
Gum arabic . . .	5	10
Glue . . .	5	0
Chlorate of potash. . .	33	7
Oxide of iron		10
Sulphur . .		5
Ground glass .		8
Manganese dioxide.		8
Bichromate of potash		8
Water . .	36	0
	100	0

(*e*) Sevène and Cahen's original sesqui-sulphide composition—

	lbs.	ozs.
Chlorate of potash .	20	0
Sesqui-sulphide of phosphorus	9	0
Ground glass . .	14	
Oxide of iron . .	11	
Oxide of zinc . .	7	
Glue . . .	10	
Water . . .	29	
	100	0

CHAPTER III

EARLY MATCH-MAKING METHODS

SPLINT cutting—The frame and coiling machines—Paraffining and dipping—" Cutting down "—Safety-box painting.

THE transition from the early methods employed, which we are about to describe in the present chapter, has been slow but continuous, and gradually improvements have been made and adopted, most of which are mechanical, but the old ways of making matches had a good innings and, until fairly recently, held their own.

Naturally, the first difficulty which would present itself to the would-be manufacturer was how to slit his timber into the proper length and shape.

Walker's original " friction lights " were cut in the crudest and simplest fashion from wooden blocks, by the aid of a hand-knife.

He employed the poor people in his neighbourhood to cut the splints for him, which he dipped by hand into molten sulphur.

These rough splinters were then tipped one at a time with his igniting composition also by hand, no machinery having been available.

Manual labour was the only medium by which the finished article could be produced.

One would tremble to think of the cost to the consumer of the present-day match, if these methods had not been supplanted by the most complicated and intricate machinery, now in almost universal use.

It was quite easy in those early days for any person to begin to manufacture ; very little capital was needed.

A pine deal, printed paper, a few pots and pans, some tools of a primitive character were all that was required.

In the Bethnal Green district of London there existed many makers, who conducted their operations in small buildings down some back street, ill-ventilated, where safety and cleanliness were alike disregarded.

Under such conditions, it can easily be grasped that fires and, where yellow phosphorus was used, disease of the jaw were prevalent.

Amongst circumstances as described, modern match factories had their birth.

Healthy rooms have now taken the place of the disgusting and reprehensible means under which the industry was primarily carried on; and to-day with the elimination of everything noxious and the introduction of mechanical means of handling practically every single operation, it is a class of work in which considerable competition exists to belong to it.

In the original factories the operations were all separate and consisted of the following—

1. Planing the pine deal.
2. Cross-cutting the deal into blocks.
3. Steaming the blocks.
4. Splint cutting.
5. Splint drying.
6. Filling the splint frames.
7. Paraffining.
8. Dipping into composition.
9. Drying the match tips.
10. Racking out.
11. Cutting down and filling into boxes.
12. Wrapping in parcels.

Planing the deal is, therefore, the first thing to receive attention.

Deals were imported from Canada and the United

States, and were supplied in planks of various lengths, widths and thicknesses.

The size most generally employed and the favourite one was 12 ft. × 3 in. × 9 in., in which 12 ft. represented the length and 3 in. the thickness.

They had been rough sawn and matured out of the tree trunk, and the rough exterior was taken off with a planing machine consisting of a frame, which supported rotary cutters, through which the deal was forced so that every small splint should present on each face a smooth appearance.

After smoothing, the deal was cut across into blocks measuring 4½ in. long × 3 in. thick.

The dimensions of an English-made match at this period being 2¼ in. long × ⅛ in. square, four and a half inches would therefore represent two matches throughout its length, the grain of the wood running in the long direction.

These blocks of wood were next subjected to a steaming process, the intention being to soften the wood, and make it more elastic before splint-cutting was attempted, as the wood without this would have proved too brittle and splintery.

For this purpose suitable ovens were provided, and a copious supply of wet steam was admitted, the block being in the steamer until it was thoroughly saturated.

The splint-cutter, before arriving at anything approaching a state of perfection, passed through many phases, but, finally, assumed the following shape shown in the figure opposite.

A is the driving pulley on shaft B, the latter supporting eccentric C, giving a reciprocating motion to shaft D, at the farther end of which are a set of lancets and a knife operating on the bottom of the block.

F^1 and F^2 are the hoppers into which the blocks are

fed and which are pressed downwards on to the lancets and knife by the ratchet wheels G.

The incisions of the lancets and the cutting of the knife were accomplished on the forward stroke of shaft D, which retreated, giving the ratchet wheels time in which to force the block down to the depth of $\frac{1}{8}$ in., the thickness of the splint. The width was provided for by the distance between one lancet and its neighbour, so

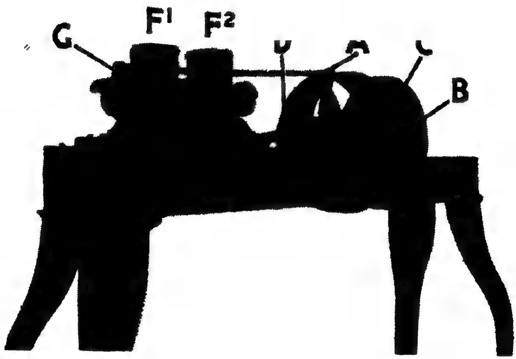


FIG. 14

A SPLINT CUTTER

that at each revolution of the machine a row of splints, measuring $4\frac{1}{2}$ in. $\times$ $\frac{1}{8}$ in. $\times$ $\frac{1}{8}$ in., was detached from the block, and fell beneath the table on to a travelling band, enabling the girl attendant to sort out any defective pieces before arranging them on trays, on which they were placed for conveyance to the drying chamber.

These rooms admit of a very short description, as they consisted solely of a closet, the walls of which were brick built, and insulated in various ways to prevent loss of heat, and provided on the floor level with steam

pipes—exhaust steam from the main engine being used, and a fan at the summit for ensuring a fresh current of air which entered at the base.

Care had always to be exercised to prevent drying too quickly as warping took place, as also too slowly to ward off the formation of vegetable bacteria or moulds, causing in the first case irregular shaped splints and, in the second, discoloration and consequent waste.

Before the advent of the frame-filling machine, which comes next on the list for definition, the splints were made into bundles and tied round by a string of such a size that a man could span round with both hands, and were immersed in melted sulphur in this fashion, afterwards being subjected to the dip in the friction composition.

Dipping in this way was attended by a great waste in consequence of the non-separation of the ends, although continual practice on the part of the dipper enabled him to separate them cleverly by a pressure at the apex of the bundle and open them at the other extremity.

In order to overcome the trouble involved in this bundle-method of dipping, suggestions were thrown out of bevelling one end, giving a splint shaped with a point.

Between the years 1855 and 1859, various provisional and complete specifications were taken out by Messrs. Bell and Black, Bell and Grimes, and T. Higgins, embodying this principle, but probably owing to its cost or, more probably still, the coming of the frame filler, bevelled tips did not long survive but gave place to more efficient and quicker methods.

Mention of one more rather ingenious attempt to overcome the clogging incident to bundle dipping must be registered.

In this the cutting was done in such a way as to leave

the splint free and separate at one end of its length, whilst at the opposite they were all attached, giving the appearance of a comb, from which a tooth, represented by a single match, could be detached at will.

Frame filling nevertheless was not to be denied, and in the year 1849 a patent for its adoption was granted to J. Palmer, who seems to have been its earliest exponent, and its arrival enabled a revolution to be accomplished by the comparative rapidity and freedom from waste, which it initiated.

The frame, of which a figure is added later on, was square or oblong in shape, and consisted of a top and bottom board, made of hard wood, and the sides of iron rods. Wooden laths, cut to the width of the frame, grooved at intervals to admit and grip a splint on the one side and covered with felt on the other, were furnished with holes at each end to fit over the side rods, and were thus kept in position.

The splint, on insertion in the frame, ran in the groove and was prevented from slipping by the pressure of the felt; the grooves and felt being alternated.

Frames were at first filled by hand, each splint being placed in position separately and receiving distinct attention, row after row being completed until, lastly, the top board was firmly screwed down with a thumb-screw or other device working from the top downwards on the iron side rods.

The size of the frames can best be computed from their total holding capacity: Between each two laths were 65 double-length splints ($4\frac{1}{2}$ in. long), and there were 60 laths. Multiplying the two figures, we get a total contents of 3,900 double lengths or 7,800 single matches of $2\frac{1}{4}$ in. each.

Bell and Grimes improved on this method in 1854, by the invention of a machine in which each row of 65

splints was filled by one movement of a lever, but not until 1865 was power used in the place of hand labour by the invention of one Simlick, who obtained protection for it in a patent.

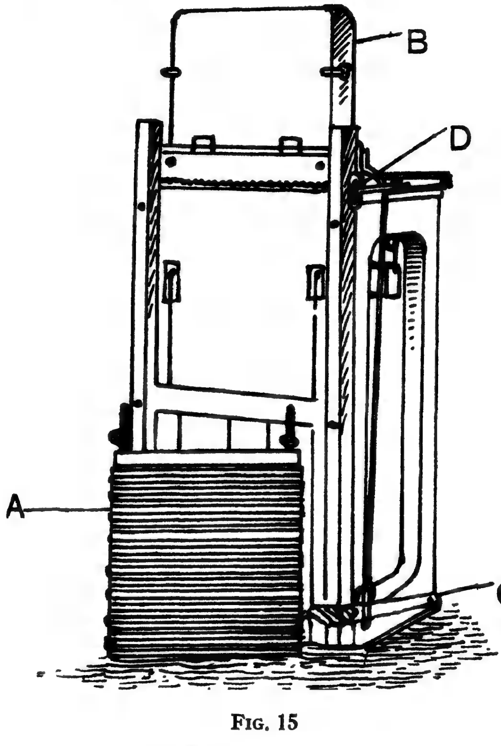


Fig. 15

A FRAME-FILLING MACHINE

A frame-filling machine such as was in constant use before Simlick's patent is shown in the figure above.

A shows an empty frame.

B is the hopper filled with splints.

C is a treadle to produce the shaking motion to enable

the splints to drop into grooves provided at bottom of the splint hopper.

D is a handle, movable backwards and forwards, to which is fixed a comb with wire teeth, working in juxtaposition with the grooves.

The frame having been placed in position at the front, treadle C is pressed down intermittently, joggling the splints into the grooves, from which position they are forced between the laths of the frame by a forward movement of the handle D.

As each row is complete, the frame moves downwards and presents another lath to be filled, and so on until the frame is finished, when it is at last clamped down by the working of the wing screws, and after a little levelling up is ready for the paraffining.

Before proceeding to give an account of the paraffining, it will be fitting here to say a few words of a novel and interesting way of producing a round frame, introduced in 1876 by E. Beecher, of Connecticut, known as "coil filling."

Coil filling supplanted frames in practically all factories in Great Britain and America, the older machines being scrapped.

The sketch overleaf will serve to convey the essential points of this latest invention.

A is a hopper into which double-length splints are introduced by the attendant, the usual and necessary oscillating shake being obtained by a small eccentric at its side.

B is a drum with grooves, the thickness of a splint, scored across its face and moving in the direction pointed out by the arrow, and carrying the splints onwards into the two intermediate wheels C and D.

Before the working of the machine begins two coils of cotton webbing, between which the splint is

finally gripped and which can be seen at E and F, are threaded one through tension wheels G, H and I, and the other through guide K, on to a bobbin keyed on to spindle L.

A wide slot in the bobbin is sufficient wherewith to acquire a tight hold; the first revolution on starting

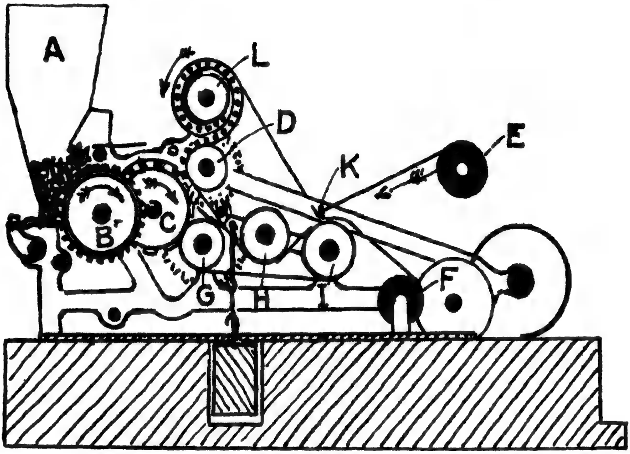


Fig. 16

COILING MACHINE

suffices to keep the webbing in position and to prevent slipping.

A clutch serves to put the machine into gear, and the filling of the coil proceeds round the bobbin until a diameter of about 24 in. has been reached, when the machine is again stopped and the end of the webbing allowed to proceed through the guide in the absence of the splint feed, and is finished off and made secure with the aid of a large pin, and the coil is detached from the machine with the bobbin in the centre.

In this way the splints are arranged equi-distant from each other and parallel, each succeeding row being kept apart by the thickness of the webbing itself.

Accompanying this " coiler " was a rolling-off machine, in which the reverse action was performed, and the splints were freed on the coil being unwound, the webbing being re-reeled in proper form to be re-filled.

There were many benefits derived from the use of this process. There was less wear and tear on the plant and machinery, greater speed and increased output. One of the great drawbacks in the use of frames was the fragileness of the laths, which were constantly breaking and scattering the matches on the ground, causing fires, etc. On the other hand, the principle of coiling could not be made continuous, whilst the frame system could and, later on, was.

Paraffining consists in so impregnating the wood at one end of the splint with the melted wax, that the kindling takes effect immediately the match head is inflamed.

In order that the amount of wax absorbed should be even and equal on each splint, a levelling up of the frame or coil is undertaken by allowing a heavy iron plate, or patter, to fall by its own gravitation on to the top, the patter being raised again in position for the next descent by means of a foot lever.

They were then compelled to travel over a steam-heated plate, to increase the facility of absorption and to stave off the possibility of a settlement of grease as an outer coating, rendering the adhesion of the striking paste difficult if not altogether out of the question.

After a short time spent on the hot plate, the frame or coil was immersed up to a depth of about $\frac{1}{8}$ in., capillary attraction doing the remainder and causing the paraffin to run up the length of the splint to about $\frac{1}{2}$ in.

distance, a turning over then was done, consequent upon the employment of the double length, and the opposite end received its quantum in the same way.

Before heating by steam came into vogue, recourse was had to direct heat from furnaces, kept alive by waste wood or, failing that, by coke. This system had the serious disadvantage of overheating, and resulted in the scorching of the wood, as it was difficult to prevent the fires from becoming too fierce, and discoloration ensued.

The level of the bath was kept at a constant depth with an overflow, and replenished from a large overhead tank of melted wax, supplied with an outlet cock directed into the bath itself.

After being allowed to cool off, the composition was affixed by the dipper.

Dipping in the igniting composition was almost invariably done by hand, and, during the period of the use of yellow phosphorus in a separate compartment, to obviate the spreading of the fumes into other parts of the factory and so contaminating the whole, the application of special ventilation fans was a necessity under regulations issued from the Home Office, and these further assured a fresh supply of air both to the room and more directly to the dipper himself.

The stone, or plate, on which the dipping was performed took the form of a square iron slab, formerly granite, situated on the top of a cast-iron water bath, kept at an equable temperature by an inlet of steam.

The composition, having been ladled out on to the plate, was spread over to a suitable depth by means of a gauge, when the ends of the splints were pressed down into the thin layer of paste, lifted out, the composition allowed to set, and at once transferred to the drying chamber.

The subjoined figure will convey the idea of a dipping

stove, and shows a coil covered with a patter for pressure purposes.

There were many patents for dipping machines of various designs, but none of them showed sufficient advantages to the manufacturer for their adoption to become general, and hand-dipping continued practically

FIG. 17

DIPPING STONE

up to the time of the introduction of the machine for the continuous production of the match.

Drying in one way was a simple operation, the only thing necessary being the provision of a chamber, usually brick built of suitable dimensions, into which the frames or coils after dipping were placed on racks, a circulation of air being assured with revolving fans, heat, when necessary, being furnished by steam pipes.

Drying, in the case of the strike-anywhere, was an

operation that required constant watching so that it did not go beyond a certain degree. If this degree had been exceeded it became a difficult matter to cut the splints in half and fill into boxes, without an enormous amount of waste from firing.

Strike-anywhere matches were, therefore, filled into boxes before complete desiccation had supervened, and, so long as the match head was dry enough to withstand the pressure of putting them into the boxes, they were considered to have arrived at the requisite condition.

Safety matches were generally allowed a little more time, and the tips of these were practically devoid of all moisture before any attempt was made to box them.

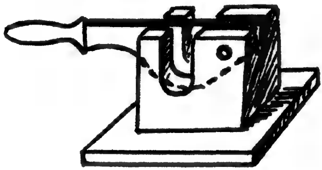


FIG. 18

CUTTING-DOWN BLOCK

In other ways the manipulation of the "safety" was substantially the same.

As soon as the drying had attained the necessary condition, the frames or coils were taken from the racks and subjected to a process of "racking out."

In the case of coils, this was carried out by the machine already sufficiently described, but with the frame-dipped matches this operation was neither so rapid nor so easy.

The frame was supported on a suitable stand erected on a wooden bench, the wing screws were first loosened and withdrawn together with the top board. In this way the grip of the boards was lessened, and the matches easily removed by hand, and placed in a heap ready to be halved.

Halving, or "cutting down," was performed by means of a block and knife, shown in the accompanying sketch,

the thickness of the block supplying in itself the gauge by which they were truly centred.

Placing into boxes was done by one and the same employee, who halved them, and they were at once wrapped into packets of dozens and grosses.

For the two latter stages of the manufacture women or girls were employed, and they became very dexterous in the manipulation, cleverly seizing at each handful the exact number for completing each box, and dexterously changing the count in the event of a larger or smaller box being given to them to fill.

Of the ordinary size box containing, at the time this method was in operation, 60 matches, one woman was capable of finishing about 30 gross a day or, in other words, of passing through her hands in that time no less a quantity than 259,200 matches, and entering them into boxes.

Box-making. Here, again, manual labour was the sole source for the turning out of this fraction of the manufacture.

" Skilletts " (French " squellettes "—skeleton) for the outsides and insides had first to be cut from a block of wood.

Canadian spruce fir was the timber employed, for the reason that it was tougher and could be easily folded without cracking owing to its superior flexibility.

A simple machine, like a joiner's hand-plane, was employed for the purpose.

A skillet is a thin veneer, about $\frac{1}{35}$ in. thick, planed off the block, and subsequently stamped where the folds are to come.

To a very great extent, box-making was a cottage industry.

Skilletts, and the printed lable for encircling it, were distributed to the maker, who took them home, pasted

and folded them into their proper shape, and returned them to the factory completed.

Drying of the paste—a mixture of flour and water provided by the box-maker herself—for this was women's and children's work—was brought to completion by the aid of the kitchen fire.

The crudity and disagreeableness of such ways and means are at once visible.

A picture of the home where a meagre livelihood was eked out by this industry in these early days of the trade can readily be conjured up by the individual with any slight pretence to imaginative capacity.

A crowded kitchen, with a mother and, probably, two, three, or even more children miserably clothed; a few articles of dilapidated furniture; a few miserable cobbles of coal on the fire; and the remains of the last meal, mostly consisting of weak tea and bread and butter; a fetid atmosphere, permeated with a mixture of smells of printed paper, wooden skilletts, and of paste being prepared on the hob, completes the description of the conditions under which boxes were made before the arrival of the modern factory with its perfectly equipped and excellently well-ventilated rooms, its radiant and happy workers for whose welfare the manager of to-day is as solicitous as he is for the quality of the goods he turns out and presents to the public for appreciation and consumption.

A piece of sand-paper, previously cut to size, was furnished with the other things for the friction, except where the box was intended for the safety match, when it was left naked, so that the specially prepared friction could be applied at the factory.

Originally put on by hand, each unit being handled separately, this method was supplanted by a simple apparatus, constructed of hard wood and provided with

two channels, into which the boxes were placed and firmly held by a slotted brass plate hinged at one end, which permitted of its being raised or lowered so as to cover the contents of the channels except just where the paint was to be put on, which was done with a stencil brush.

FIG. 19

HAND PAINTING MACHINE

The idea underlying this first attempt at a painting machine can be gathered from the sketch above.

The portions of the boxes to be painted with friction paste will be seen exposed on the upper part of the apparatus, the handle observed was for pressing them tightly together to prevent paint running down between.

Wrapping into parcels, the final and concluding step except putting them into cases, was, like most of the other operations, done by hand and needs no definition.

Cases were never prepared or put together inside the premises, but were bought as required from a case-maker.

But the modern man has adopted different ideas, and cases are now partly made under the same roof as other processes, even printing box labels and wrapping papers being finished there.

Separate departments are equipped for all the miscellany of work accessory to the main purpose.

In the following chapters an endeavour will be made, with the aid of diagrams or sketches, to explain to the reader the mode of working of the modern machinery as employed at the present moment almost throughout the whole of the match world.

CHAPTER IV

WAX MATCHES

Rush-lights—Cotton counts—Taper making.

Wax vestas. Wax vestas were a later development than wooden matches.

Probably the earliest were "rush-lights," a species of candle, which were anciently much in vogue.

The ordinary rush was carefully dipped in grease with a little wax added.

Rushes were cheap enough, and it is stated that from these primitive wax stems a poor man might enjoy 5½ hrs. comfortable light for the sum of one farthing.

The first English patent for this class of match was taken out by W. Newton, in 1832. Many mixtures for the preparation of the stem have from time to time been tried, mostly with a view of cheapening, all containing either paraffin wax or stearine or mixtures of the two.

Stearine is the one wax now generally in use, this being hardened and rendered less friable by the addition of fat soluble gums, such as gum dammar or copal. It will be unnecessary here to describe the manufacture of this variety after the stem is produced, as it is practically the same as the frame method for wooden stems, but a description of the process of preparing the taper will be helpful.

Wax vesta stems are constructed of cotton, stearine and gum.

The cotton selected is usually known in the trade as 16^s count, which implies that 16 hanks, each hank 840 yds. long, will weigh exactly 1 lb. By the process of spinning the raw cotton and afterwards bleaching, the

manufacturer of wax vestas procures his cotton in the shape of a bale or reel. These reels vary in their specification in accordance with the thickness of the vesta it is intended to produce.

The vesta intended for the English market is formed from a reel of the following description—

It contains 50 to 100 strands, each strand being composed of 30 threads. It may be any suitable length, but 1,500–2,000 yds. is general.

For manipulation in a frame machine 72 strands was the accepted quantity for the above thickness. In order to convert the 72 strands of cotton into taper, a quantity of stearine and gum is melted together and conveyed to a steam jacketed and enamelled pan. The strands of cotton are then led through a suitable guide and immersed in the melted fat, and further conducted through a perforated plate, the holes in which are the exact size of the vesta desired.

A revolving drum driven by power, about 9 ft. in diameter, operates to draw the total length of the cotton through the fat and plate. From this drum the partly completed vesta is retaken through the same pan and wound on to another drum of the same size on the opposite side. This action is alternately done for five or six times until the taper is complete. The melted wax is allowed to get gradually cooler at each successive round, so as to complete the taper. As soon as the filling-up process is complete it is ready to be polished, this final operation being performed by very quickly passing the taper through the perforated plate made especially hot for the purpose. A portable drum serves for the placing of the product in front of the frame-filling machine. The remainder of the operations is identical with those for wooden matches already described.

Continuous machines are now employed and are of similar construction to those in use for other kinds of matches.

The difference chiefly consists in the fact that "paraffining" is not necessary, seeing that the vesta is already provided with its igniting medium in the stearine of which it is partly composed.

CHAPTER V

VESUVIANS

" Braided lights "—" Bengal lights" —" Double-dip " matches.

Vesuvians. Here, again, the manufacturing process is the same as that adopted for the making of the ordinary matches by the frame method.

This variety of match has almost had its day, and is practically extinct, or the small trade still existing is not of sufficient importance for inventors to apply their ability with a view to the improvement in the methods.

Round splints are used for these lights, originally imported from Austria.

To further their production, three separate and consecutive dips of three different compositions are required, each one being allowed to dry thoroughly before the succeeding one is applied.

The first dip is a small one, and consists of a core of very slow burning and, to a large extent, non-fusible materials, the principal constituents of which are composed of infusorial earth, charcoal, and very coarse nitrate of potash, held together by gum arabic.

If a light be applied it will just slowly burn.

The second dip is considerably faster and burns rapidly, retaining its heat for a long time; and the component parts are chlorate of potash, nitrate of potash, charcoal, and incense or other pleasant smelling material, such as cascarilla bark or satin wood dust and, again, gum arabic.

The third dip is that portion which is ignited by friction,

and when struck communicates its flame to the bulb formed by the first two.

The sketch of the vesuvian given below will perhaps make this description clear.

The object of the first dip, or slow core, is to prevent

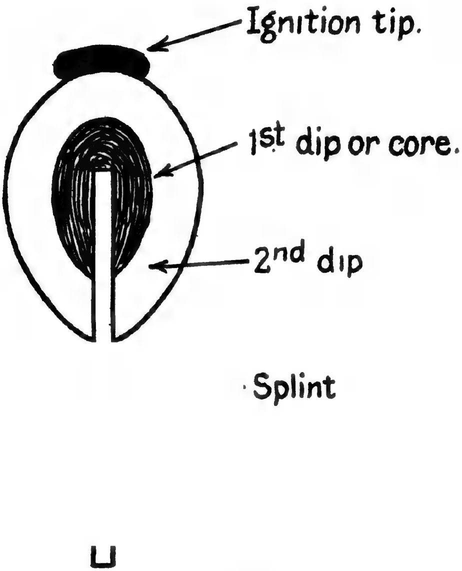


FIG. 20

SECTION OF VESUVIAN

the bursting of the whole bulb when it begins to burn, and to moderate the combustion as well as to preserve the temperature of the bulb after the actual combustion has ceased.

If the whole solid mass were composed only of the same composition as the second dip contains, the large volume of gas given off from the centre portion would

not find vent in time, and a miniature explosion would occur, burning particles being thrown off.

The emission of gas from the centre, or core, only takes place very slowly, with the result that an even and continuous inflammation is achieved and accidents prevented.

A variety of vesuvian which found a market at one time in considerable quantities was the one known as the "braided light."

In this one, the wooden stem was made stronger by two fine pieces of wire running up each side of the splint, and kept in position by threads plaited round and embracing the splint and wire.

The aid of a braiding machine was called in for this purpose, working on the principle of the dancers round a maypole, in which the pole is represented by the splint, and the cotton threads are the ropes attached to the top.

Fixation of the threads was assured by passing the splint and enveloping thread through a flour-paste and afterwards drying.

The splints for this purpose were a special type about one yard long. Cutting to the required length took place as soon as the drying was finished.

It has been stated that the original idea for the braided light emanated from the hoops surrounding the early Victorian "crinoline," the wires of which were plaited round in a similar manner.

The advantage claimed from the provision of the two wires was, that the head, or bulb, could not be detached when pressed on to the surface of the pipe.

Non-combustible stems have been made so as to embody the same intention, consisting of glass, slate, wire, etc., also a primary dip of gum and asbestos, the last one to prevent combustion of the wooden stem on

which it was affixed. None of these is surviving now. They are interesting only as old landmarks of the industry.

Bengal lights are another type of vesuvian rendered familiar by the frequency of their use on children's excursion parties.

These lights are as a rule more the care of the maker of fireworks than that of the match-maker.

They are made to produce various brilliant colours when burning, the salts of Barium being used for green, whilst crimson is the result of the decomposition of the compounds of Strontium.

Double-tip matches, fairly recently introduced, have not reached a great amount of popularity in this country, but are very widely distributed in the United States of America.

These double tips are capable of being produced on the continuous machine, as the combined dip is practically the same size as that of the ordinary match and, therefore, gives but a slight amount of extra trouble in the process of drying, and in this respect cannot be compared to the vesuvian, the size of which required special steam-heated rooms.

The first dip of these matches consists of a highly inflammable composition not ignitible by friction; and the second, an extremely sensitive tip in which is embodied a large proportion of sesqui-sulphide of phosphorus and chlorate of potash.

The originators were R. and D. Maguire, in 1898, yellow phosphorus being at first largely used in the manufacture.

Small quantities are prepared for the market in this country by Messrs. Bryant and May, Ltd., and are sold under the names of "Bird's Eye" and "Club Matches."

Continuous matches have also had their advocates. The principle of the idea is to spot at intervals a

piece of narrow tape with dabs of ignitible composition, the tape being wound in a coil and withdrawn through the outlet of a circular pocket box, made of metal. The act of drawing the tape causes the dab to take fire and ignite the tape.

As a plaything, and perhaps for a short period a novelty, they deserve only limited attention, and have never been seriously entertained.

CHAPTER VI

THE MODERN MANUFACTURE OF MATCH BOXES

DEBARKING machine and cross-cutter—Peeling and chopping—Inner and Outer box machines—Drying cupboard—Sanding and painting machines.

THE conditions under which modern match-making is carried on have entirely changed in recent years; it can be asserted almost without question that hardly any connection exists between the old and the new processes.

During the last 20 years the improvements, both in respect of machinery and building as well as in the status of the operatives, have been so amazing progressive, that it would puzzle an old manufacturer of the former period, coming to life again, to recognize his own industry.

From being a business, practically all of which was manipulated by the application of manual labour, there is scarcely any operation at the present moment that is not brought to completion by machinery of the most wonderful and intricate description.

An endeavour will be made in the following pages to explain, as far as is possible in detail, the various operations connected with the preparation of the modern match.

Diagrams, or sketches, will be shown in order to enable the reader to follow more closely the steps involved.

Wood, or chip box-making, will be the first item to claim attention, the primary or initial stage of which consists in the—

Debarking and cross-cutting of the logs. Logs of wood imported from abroad, chiefly from Russia and Finland,

in which countries there is found an ample supply of the right sort, viz. aspen.

Except in special cases, where a softer wood is required and one which is more easily kindled, aspen is almost universally used for the making of the boxes as well as the splints.

The aspen logs, of a convenient length and diameter, viz. about 8 ft. long and from 10 to 24 in. cross-section, having been imported in quantities sufficient for a 12 months' consumption, are stored handy for use in the available yard space of the factory, and are from there conveyed into the room where the cross-cutting saws are situated.

Saws of a circular description are in common use as well as others of the reciprocating type.

Logs are cross-cut into convenient lengths, mostly about 26 in., the manufacturer making it his concern to cut into those lengths wherein he makes the minimum of waste.

The stripping of the log of its bark is accomplished by means of a specially constructed machine, exhibited in the ensuing sketch.

This machine consists of a circular rotating disc, into which are fitted knives at sufficiently wide intervals; the cutting edges of the knives project slightly in front.

The speed of the machine is set at about 350 revolutions a minute.

The short log of aspen, having been stood up in a vertical position on the platform, is continually pressed by the operator against the rotating disc B and comes, therefore, in contact with the projecting knives, one of which can be observed at C.

The handle D, on the top of which is a steel bobbin, is the agent by which pressure is brought to bear on the log, in order to force it against the knives and

accomplish the stripping of the bark. One man is sufficient to attend to the working of this : its capacity being equal to a fairly large factory.

The logs being now stripped of their outer shell are delivered to the room in which the veneering or peeling machines are situated.

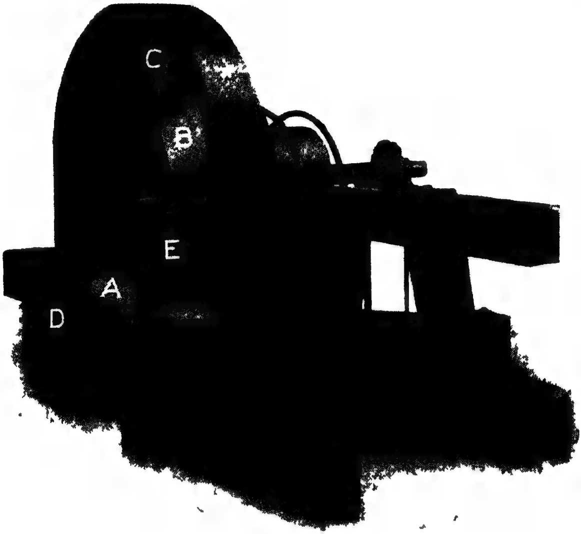


FIG. 21

DEBARKING MACHINE

By the action of the peeling machine, the log is slit up to within about $2\frac{1}{4}$ in. diameter, into thin continuous shavings about $\frac{1}{30}$ in. thick for boxes.

The principle of this is similar to an ordinary mechanic's lathe.

An illustration of the peeler is given on page 75, from which its working can be understood.

A is the driving pulley, the machine being belt driven.

B shows the log of wood in position, and on starting the machine it is given a revolving motion in the direction shown by the arrow. On the opposite side of the log, as shown, is situated an ordinary steel knife, against which the log is continually actuated, and which results in shaving off a long length of wood veneer, which accumulates to a sufficient depth on to a table provided for the purpose.

A little in advance of the cutting-knife are situated a series of lancets, which are used for the purpose of scoring the veneer at the points where finally it is to be folded, when the moment has arrived to complete the operation of transforming the shaving into a match box.

The result of continually detaching the veneer is that the log left in the machine constantly becomes smaller at each revolution, and, unless means were used to counteract this feature, the knife and lancets could no longer operate.

In order to compensate for this reduction in diameter of the log, a worm gear is at work, situated under the table, forcing the knife to approach at the same speed as the log becomes smaller.

At the moment when the size has been reduced to about 2¼ in. diameter, the machine is automatically stopped, the remains abstracted from their bearings situated at C and D, which grip the log tightly to prevent its slipping when the knife is put into operation, by forcing the points of the bearings into the wood at each extremity of the log.

The veneer is allowed to accumulate on the table already mentioned until it attains a depth of 12 in. or more for convenience in chopping into the required width for each box.

In order that a more comprehensive appreciation may

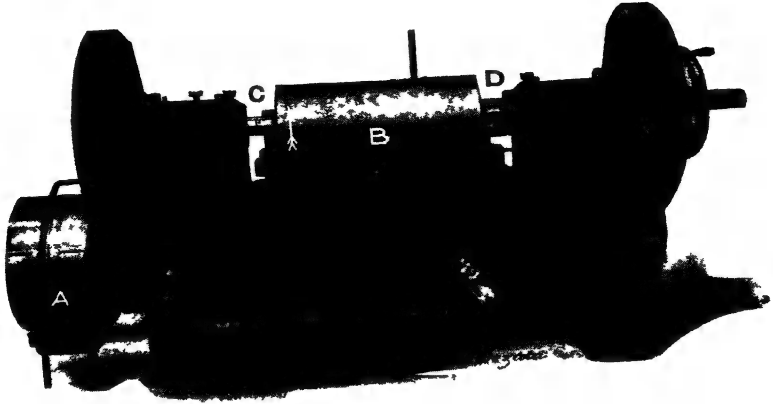


FIG 22

FRONT VIEW OF PEELING MACHINE

be obtained of this machine, a second sketch is shown opposite, from which the reader will be enabled to obtain a view from the opposite side, and get a clearer idea of the operations of the veneer knife and the lancets.

A shows the knife and B the lancet box, from which protrude the lancets. C is the table of the machine, which, as a general rule, is supplemented by a wooden extension where the shavings accumulate.

The lancet box B is shown thrown back at the moment for convenience when the insertion of a fresh log occurs.

The average outturn of a peeling machine is about 130,000 skillets, which is synonymous with boxes of the usual pocket size.

Chopping the veneer into the requisite width is the next process, and here again a sketch is shown (page 79), which will convey the principle underlying its working. A description will again be helpful—

A is the table on to which the accumulated veneer is brought from the peeler.

A certain amount of packing up and squaring having received attention from the person in charge, so as to ensure accuracy of cut, a proceeding the necessity of which would be apparent when the skillet came to be made up into a box, the belt guide B is pushed over on to the fixed pulley C by means of handle D, when the action of chopping commences.

E is a guillotine knife working eccentrically on shaft F, communicating an upward and downward motion to the knife E, cutting off at each stroke the needed width of veneer for a single box.

The necessary amount of continuous feed is provided for by feed roller G.

By raising or lowering the arm H at point K, any adjustment can be made so as to provide for a wide or

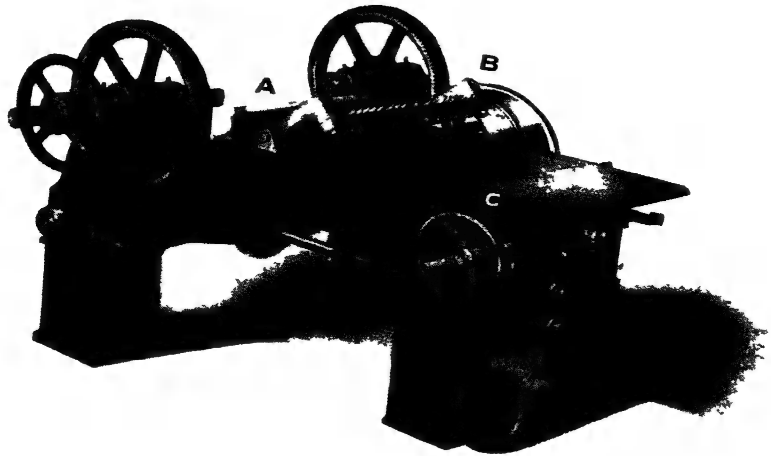
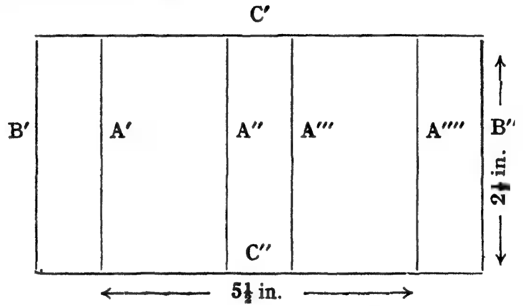


FIG 23
BACK VIEW OF PEELING MACHINE

narrow skillet as desired, as by this means the travel of the veneer can be controlled.

In order that a clear conception of the progress made up to this point in the preliminary preparation of a match box may be had, a diagram of the unfolded skillet is shown, an ordinary size of the cover having been selected for the purpose in view.



OUTER COVER OF MATCH BOX

The dimensions, as shown, of the piece of shaving are $5\frac{1}{2} \times 2\frac{1}{2}$ in., and the thickness about $\frac{1}{30}$ in.

A′, A″, A‴, A⁗ represent the scoring marks as applied by the lancets of the peeler or veneer machine.

B′ and B″ are the edges cut by the lancet pushed sufficiently forward to sever the shaving at these points.

C′ and C″ are the edges severed by the chopping machine.

Almost any dimension of skillet, within reasonable limits, can be obtained by an adjustment of the distance between the scoring and cutting lancets of the peeling machine and the length of throw on the chopper.

The prepared skillets which collect in front of the knife are now examined by a woman attendant, who throws out the defective ones made up in conveniently

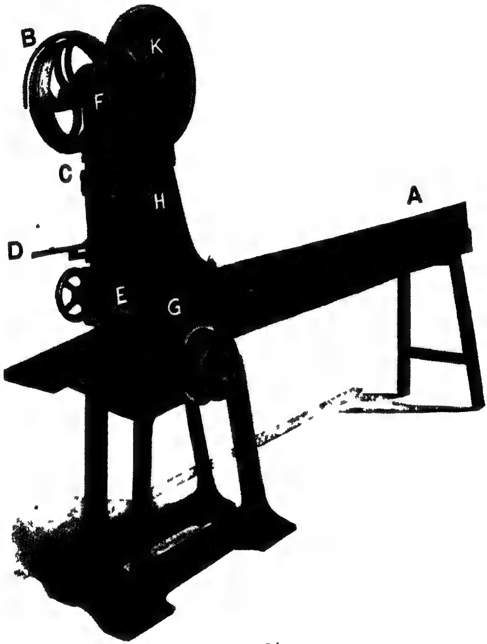


Fig. 24

CHOPPING MACHINE

sized bundles and conveyed to the box-making department to be finally made up into boxes. 300,000 skillets per diem is the capacity of the chopper.

Up to the present the operations have been more particularly appertaining to the one part of the box, viz. the outer cover, and we will, therefore, continue and finish the description of this item, so that a clearer idea may be obtained and unnecessary confusion avoided.

The outer cover of the box, it will hardly be necessary to state, is that portion to which the label is attached, and a description of the mechanical contrivance to complete will be given.

The complicated nature of the outer box-making machine is such that it is difficult, even with the help of a sketch, to define in detail all its working parts, but a general outline will no doubt convey to the mind of the reader how large numbers of boxes are furnished in the modern match factory.

The figure opposite shows the outer box-making machine.

In taking stock of the figure, it will be observed that the power emanates from the pulley A on the right-hand side.

A friction clutch operated by the handle B serves to put the machine in motion.

Running from the pulley end to the opposite side is a shaft properly supported on cast-iron pedestals attached to the table.

To this shaft are fixed numerous cams of all shapes and patterns, from which source all the necessary motions, operating in many directions, are derived, with the object of applying vertical or side movements wherever they are wanted.

The prepared skillets are packed in the box C in an upright position.

Fig. 25

OUTER BOX MACHINE

The already printed and cut-to-size labels are then placed in the box D, at the farther side of which is the box E, containing the paste; under the bottom of the paste box is a worm or screw, working so as to ensure a supply of the adhesive for enabling the paper label to cleave to the wooden shaving and forcing the paste through a perforated grating, and so producing an even and efficient spread.

Assuming now that the machine has been set in motion, the first thing that happens is that slide F, furnished in one part of its length with a slightly projecting notch, moves downwards and in its descent engages by means of the notch one skillet, forcing it out of the box C and on to the forming mandril G, which is of the exact shape and dimensions as the inside measurements of the case or outer of the box.

Immediately the skillet has been pushed far enough in a downward direction, so that the centre of it engages the mandril, it is given a further thrust towards and in the direction of the label hopper. Almost simultaneously another skillet is freed, as already described, from the container, to be again enfolded round the mandril. In this way there occurs a continuous procession of box-forming shaving towards the labels and paste.

As soon as the first skillet has got into position exactly *vis-à-vis* the label hopper D, a pair of fingers, arranged to open and close, as they move to and fro from hopper D to mandril G, seize a label, which by constant dabbing has been smeared with paste issuing through the grating already described, and draw it forward and place it in the exact position on to the top of the skillet.

Further motions of the machine are then brought into play for finally folding the label round and thus completing the box, when it is finally ejected at K, finished, but in a wet condition, and falls on to a moving and

endless band constructed with wire netting and carried forward to a drying cupboard.

In the machine just described, we have been dealing with the outer cover only. In order, therefore, to complete the formation of the wooden or chip box, a description of the machine employed for the manufacture of the sliding or inside portion, which holds the matches, will be given.

A machine for this purpose is shown on the subjoined sketch.

It will not be necessary to describe again the manner in which the two portions of this half of the completed box are prepared, as it is effected in the same way as that of the outer portion, an adjustment of the cutter and lancets on the peeling machine and chopper being the sole alteration wanted.

The inside is, as can easily be understood, composed of two skillets, viz. the rim and the bottom, both of which are held together by means of a strip of paper.

In this machine, just as in the case of the foregoing one, the starting is effected with the aid of a friction clutch at A.

The narrow strip of wood forming the oblong portion of the inside, generally called the "rim," is fitted into the holder C, whereas the "bottoms" are placed in a long channel vertically at B.

At once the turning out of insides begins, directly the clutch is put into action.

At D, is situated a paste box, under which runs a strip of paper from a reel provided of the width required, and there it receives a thin coating of paste, the thickness of the paste being controlled by an india-rubber gauge, situated at the outlet of the paste holder at E.

The strip is now drawn forward to the length prescribed by means of the finger F, from whence it travels

under the skillet holder C, whilst at the same moment a "rim" is forced out and at once seized by a revolving mandril G, provided with a clip, which at each revolution automatically opens or closes, when either in the act of seizing a fresh rim or releasing one just completed and covered with the pasted paper.

It will be noted that in this case the mandril itself turns round and in that act does the folding. In this respect it differs from the same thing on the outer machine, in which the mandril is stationary and the folding is accomplished by the agency of levers.

At the moment of forcing out the rim, the pasted paper, drawn forward as described, comes into contact with the flat side of the rim and receives a dab from a specially formed lever, compelling it to adhere and so follow round in the revolution, and the required length is detached from the reel by a cutter actuated from below and not visible in the sketch.

At each revolution of the machine one bottom is pushed in front of the mandril K, and is momentarily held in its position with a spring.

K is stationary and does not move round, but can be moved backwards and forwards.

G has now possession of the rim and paper and K the bottom, and moves forward towards K, fixing the rim and paper on to K, and retires again for the reception of further supplies.

The final folding of the edges of the paper is done by means of fingers acting on all four sides of the inside.

K now moves backwards in order to detach the finished article, and to accomplish this final operation the edge of the box is brought into contact with a projecting notch and is thereby released, and is thrown forward into a suitable receptacle, or on to a conveyor for the purpose of transporting it through the drying cupboard.

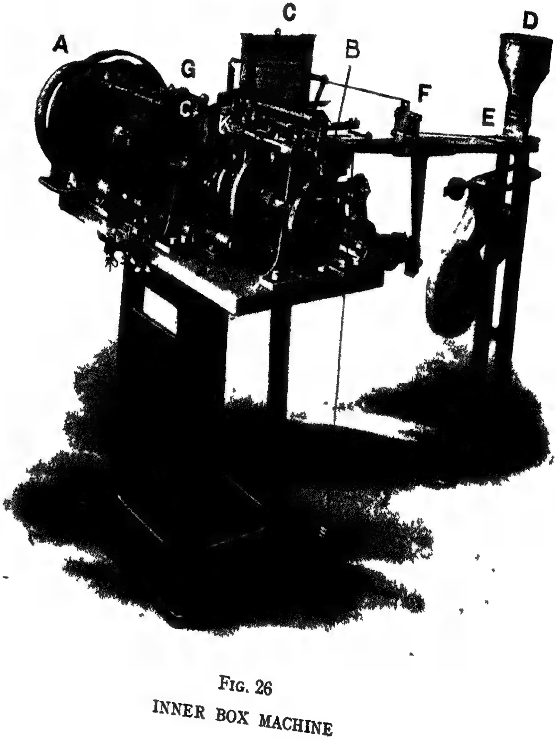
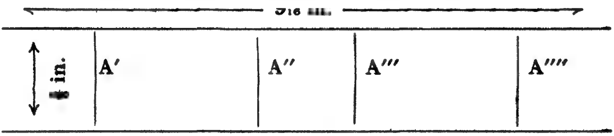


FIG. 26
INNER BOX MACHINE

As in the case of the outer machines, practically the whole of the motions are derived from the one cam-bearing shaft on which is situated the clutch at A and the driving pulley.

Diagrams showing the exact size of the rim and bottom used on this machine are displayed below—



RIM SKILLET FOR INNER

A′, A″, A‴, A⁗ show the scoring marks where folding occurs.

2⅛ in.

BOTTOM

Owing to the tendency of wood to shrink in the drying, bottoms are very often cut from cardboard to the size required in an ordinary guillotine.

The production of outers per diem for a single machine, where the material is of good quality, can reach as much as 300 gross, the inner production being about the same, the attendance necessary amounting to one girl and the power required being $\frac{1}{10}$th h.p., respectively.

The possibility of procuring an enormous output can therefore, readily be grasped, and the old method by

which the box was made by manual labour has been made to appear somewhat ridiculous.

Having now brought both parts of the box to completion, we can attempt a description of the next step.

It will not have escaped the notice of the reader that the boxes, when issued from the machine, must naturally be in a very wet condition, due to the presence of the paste used, which consists mostly of stárch or flour and water, and that they will need to be dried before it is possible to fill them with matches.

To the uninitiated this would in all likelihood have the semblance of a simple process, whereas in effect a great amount of care has to be bestowed to procure a good result, and to prevent the waste of all the material used and the labour involved up to this point, which is considerable.

Owing to the fact that, in producing the two parts of the box, a certain amount of paste has been squeezed out and partly covered the outsides, a great number of the boxes would be found cleaving to each other when dry and could not be separated without tearing them asunder. This primary trouble is obviated by setting the box-making machines, so that each one is delivering its product on to the conveyor in a different line of march, rendering it improbable that they can lie together in a huddled-up condition.

Drying too quickly causes other troubles, for, if too rapid drying is resorted to, a condition known as "cockling" results.

"Cockling" is the blistering of the paper attached to the box, due to excessive heat having been applied especially in the early stages of the desiccation.

It has therefore been found advantageous to provide for this process a specially constructed apparatus, built on such lines that only a moderate temperature is

brought into play in the early stages, and an increased heat when the drying is almost completed, assuring in addition that a turning over is at the same time accomplished.

Such a result has been achieved by the box drying cupboard, an illustration of which is given opposite.

The illustration almost explains itself. Boxes, either insides or outsides, fall from the machine directly on to the transporter, which can be almost any length agreeable to its capacity and the number of machines it is intended to accommodate, and are conveyed along towards the cupboard.

As before stated, a different line of progression is provided for each box, which can be seen by reference to the drawing.

Up the inclined plane the boxes are then carried until they reach the top, when they are subjected to their first turnover, effected by a fall of a few inches on to the first or top storey, and then travel along on wire-netting supports to the opposite end.

Five storeys are commissioned, this being as a rule sufficient for complete desiccation, and in transferring from one storey to the one next beneath a further turnover is brought about so as to ensure continual separation of each unit.

A fan is provided to exhaust hot and saturated air from the summit, whilst the air admitted at the foot passes over a series of steam-heated radiating pipes. The hottest portion is at the lowest stage and the coolest at the top.

Inners and outers are as a rule treated as separate entities and not dried in the same machine.

A drying cupboard of this calibre is calculated to deal with 150,000 complete boxes per diem or 300,000 inners and outers separately.

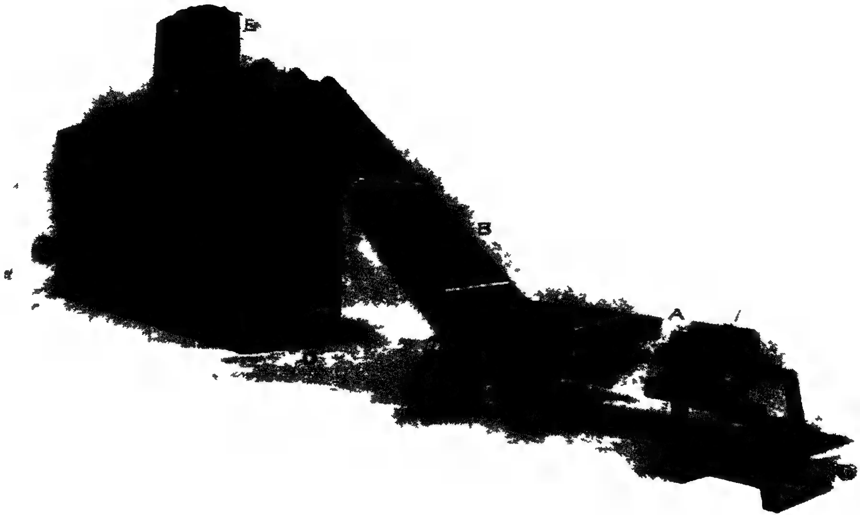


Fig 27
BOX DRYING CUPBOARD

Two further steps are now wanted in order to bring the boxes into a condition in which they can be made acceptable to the modern match machine.

In the case of the box for the strike-anywhere match, there is the provision of the sandpaper friction attached to the side of the box and the fitting of the inner portion into the outer, this latter operation known as " nesting."

With respect to that required for the safety match, there is the painting of the specially prepared friction surface, and, as in the case of strike-anywhere, the " nesting."

Boxes intended for the last-named match are painted after being filled with matches, but the former are sanded before and indeed by the machine shown opposite.

The sandpaper, being supplied in reels at A, is fed up to and under roller B.

The boxes to be provided with friction sand are contained in a suitable bin and are fed by hand into shoot D.

On arriving at the bottom of the shoot they are pushed forward with a plunger under the pot containing paste E, from which the flow can be regulated, into a channel keeping them in position.

As each one receives its quantum of paste in its passage, a further advance is made until the arrival opposite roller B, at which point the narrow strip of paper is guillotined off by a small knife to the correct width, and at the same moment pressed down by a stamper on to the pasted portion to which it will adhere and is then permitted to dry.

The capacity is about 350–400 gross a day with the assistance of two girls.

" Nesting," which is the final operation, is manipulated in a further machine. Simple in construction and readily pictured in the mind without, in this instance, the provision of a diagram or drawing.

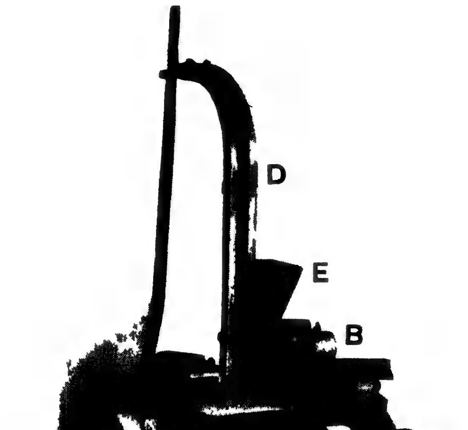


FIG 28

SANDING MACHINE

The machine is constructed with two shoots, down one of which the "outers" are fed, whilst the "inners" slide down the other. The two portions are then made to approach each other by the action of plungers, so that they are exactly opposite; whilst they are in this position a final thrust is administered to the inside portion and compelled to fit into the "outer" ready with its mouth open for the reception, when the operation is complete, and the combined units made ready for the match machine by packing them in a convenient manner into cases holding a suitable number; usually 30 to 40 gross.

Although the boxes intended for safety matches are not supplied with the specially prepared friction surface until after they are filled, the reason being that the mixture of painted boxes with the matches coming off the machine would give rise to accidental fires in the factory, and this might give rise to a similar occurrence when the safety match was in the hands of the consumer, it will be convenient and appropriate to give a description of the painting machine here, and the annexed figure will indicate the nature of the work performed.

At A the boxes are supplied to the machine on their edges and are carried forward and up to the mechanical portion by band B.

C′ and C″ are rollers circulating in a basin of the mixture to be applied, each one fitted with an adjustable gauge, guaranteeing the proper depth, in order to obviate the efflux of too plentiful a supply, and to prevent daubing.

D′ and D″ are brushes moving round primarily impinging on rollers C′ and C″, and, secondly, carrying forward the paint on to the upper and lower sides of the box respectively.

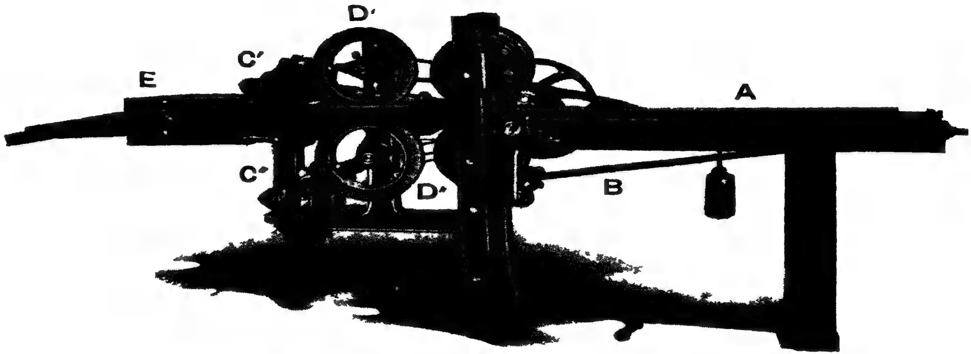


Fig. 29
PAINTING MACHINE

The brushes revolve in the opposite direction to which the boxes are travelling, and the latter are thus between two opposite but conveniently unequal pressures, the band B compelling them under the brushes whilst the latter are retarding, thus ensuring that, at the moment the paint is put on, the boxes are firmly pressed one against the other, so that the space between them is reduced to a minimum, and the paint is prevented from running down between and in the niches.

The boxes are filled before being directed through this machine, as they are in a more compact condition, and are, therefore, more capable of withstanding the pressure to which they are subjected.

Empty boxes are liable to bulge inwardly and prevent a regular spread.

The drying is consummated in a covered way E (portion of which is only shown), provided with either a mechanical blower or steam pipes, or perhaps both, according to circumstances and situation.

The capacity of a machine for this purpose reaches 1,000 gross of boxes per diem, two girl attendants being necessary.

CHAPTER VII

SPLINT CUTTING

Splint chopping machine—Drying machine for splints—Cleaning and straightening machine.

Splint cutting. Splint cutting up to a point follows the same lines as skillet making for wooden boxes. The logs, cut to the size convenient, are debarked and veneered on similar machines.

The veneer, instead of being shaved off to the thickness of $\frac{1}{30}$ in., as is the case with the boxes, is cut to the thickness of a splint, usually $\frac{1}{10}$ in. Other thicknesses are made, depending on the size of the match to be prepared.

There is no scoring done on the veneer machine, as no folding point on the splint is necessary, and we are, therefore, confronted with a somewhat different proposition, in which the chopping machine, perhaps, takes the premier place.

It will, therefore, be convenient to assume that a supply of plain splint veneer has been provided, and that it has been carried from the veneer machine and placed to a considerable depth of 12 to 15 in., on the table of the chopper, ready for the chopping to commence. The chopping machine for this purpose deserves an illustration and is, therefore, given one on page 97.

Table C is where the veneer is piled up.

D′ and D″ are the fast and loose pulleys for starting or stopping the machine.

A feed roller is provided for forcing the travel of the packed veneer under the knife and cross-cutters, shown at B and A. This machine is provisioned with

cross-cutters sufficient to detach five splints at one revolution of its action, from veneer of $\frac{1}{10}$ in. thickness.

The knife and cross-cutters, both fixed on to the same frame, and working vertically up and down, are moved by means of eccentric shaft F.

It will be convenient to take for granted that the knife and lancets, or cross-cutters, are both at the top of the stroke, and in a position to commence their work of chopping off the splints from the many layers of packed veneer on C.

The feed rollers, of which there are two—one on each side, but neither of which can be discerned—have driven the veneer forward to the thickness of one splint, ready for the lancets, which are the first to come into contact with the wood to be operated upon, to be followed immediately afterward by the knife, cutting the whole width of the veneer in the direction of the grain.

The lancets, cutting in the opposite direction to the knife, are set apart at such a distance as to allow for the length of the splint desired, and bearing in mind that the thickness of the veneer is $\frac{1}{10}$ in.; it can now be understood that, at each fall of the two kinds of cutters, showers of match sticks about $1\frac{3}{4}$ in. long $\times$ $\frac{1}{10}$ in. wide $\times$ $\frac{1}{10}$ in. thick have been severed off.

To give an example, if the pile is 15 in. deep, then 750 splints are prepared at one stroke.

The speed is worked up to 100 revolutions a minute, so that a simple sum in arithmetic would give us a quantity of 45 millions as an output in a 10 hours working day. This number is, however, never attained, as a considerable amount of time is absorbed in repacking and adjusting, but at a moderate statement 15,000,000 to 20,000,000 splints can be relied upon, with the attendance of one man.

Before the splints are ready for the final part that

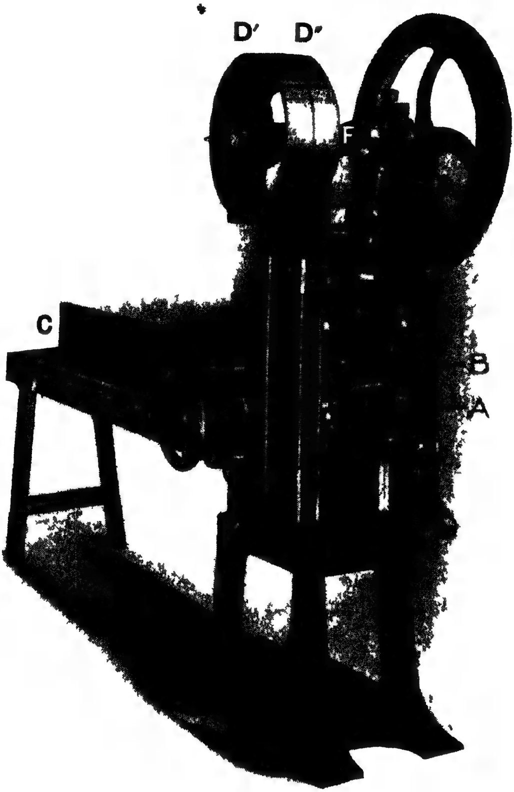


Fig 30

SPLINT CHOPPING MACHINE

they play, they are subjected to one or two more treatments, in order to furnish them with the compulsory physical condition, before their conversion into friction matches.

They must be subjected to an immersion in a chemical bath, composed of a hot solution of phosphate of ammonia, so that they do not exhibit glowing particles after the flame is extinguished.

For the furtherance of this end, the splints, as they emerge from the chopper, are collected and carried forward to the receptacle in which the drying is to be carried out, and the whole apparatus douched overhead in the solution, sufficient time being allowed in order that a thorough saturation should be effected.

Additional ammonium phosphate is from time to time added, to maintain the strength of the bath.

On the impregnation being complete, the splints are extracted and, still in the same repository, introduced to a specially constructed drying chamber, of which there are many patterns.

It will be sufficient to describe one of them.

The problem of splint drying, like that of box drying, presents many difficulties, and is not so easy as it might seem.

During the drying, to allow the splint to remain in a static condition is generally fatal, for which reason dryers are constructed so as to keep continually on the move, and are furnished with a supply of hot air.

By this means the result is arrived at without in any way altering the shape.

If one edge of the splint is exposed to the hot air unduly, the loss of moisture takes place unevenly, and buckling is the consequence, giving rise to what are technically termed "dog-leg" splints.

"Dog-leg splints" must be studiously avoided by the

match maker. They impede nearly if not all the subsequent operations, especially at the moment when they are required to be punched into the match chain.

They refuse to fall straight into the grooves provided, into which they have to be coaxed, nor will they hold their heads up vertically during the dipping process, but persist in standing at an angle, and make the acquisition of a neat round dip impossible and, finally, seriously interfere with the daily production, which is felt throughout the whole factory.

Splint drying machines are, therefore, built of a circular pattern and revolve the whole time, so as to present each edge of the splint in its turn to the action of the hot air, and thus attain an equal drying effect through the whole.

A section of one type of dryer is shown on page 100.

A shows a circular dryer protruding from its cupboard, of which there are a series, each one communicating through air inlets with its neighbour, and into which it can be pushed and the door closed on it.

The dryer is constructed of strong perforated casing and revolves on a bearing at each end. The object of the perforations is to permit a free access of air, which is provided by a fan situated on the roof, communicating alternately with each section.

During the drying the splints are freed from a large amount of dust and small lengths of wood, which are ejected into the atmosphere, or otherwise disposed of by burning them as fuel.

The friction engendered by the constant moving of the contents serves also to polish the surface of each individual splint, and so gives them a more acceptable appearance.

After the completion of the drying, the splints are further subjected to a cleaning and straightening process.

Inside the dryer they are in nothing more nor less than a higgledy-piggledy state, and from this condition it is inevitable that they should be released.

The inversion of an ordinary box of matches by accident, and the nuisance and difficulty of gathering them together, as well as replacing them in their former position

FIG. 31

SPLINT DRYING MACHINE

in their box, is one of those problems present to the mind of the average person.

It is, therefore, no small achievement, that a method of mechanically dealing with these obstinate pieces of wood has been created, and one which is capable of taking hold of countless splints and placing them in straightened rows at the rate of millions per diem.

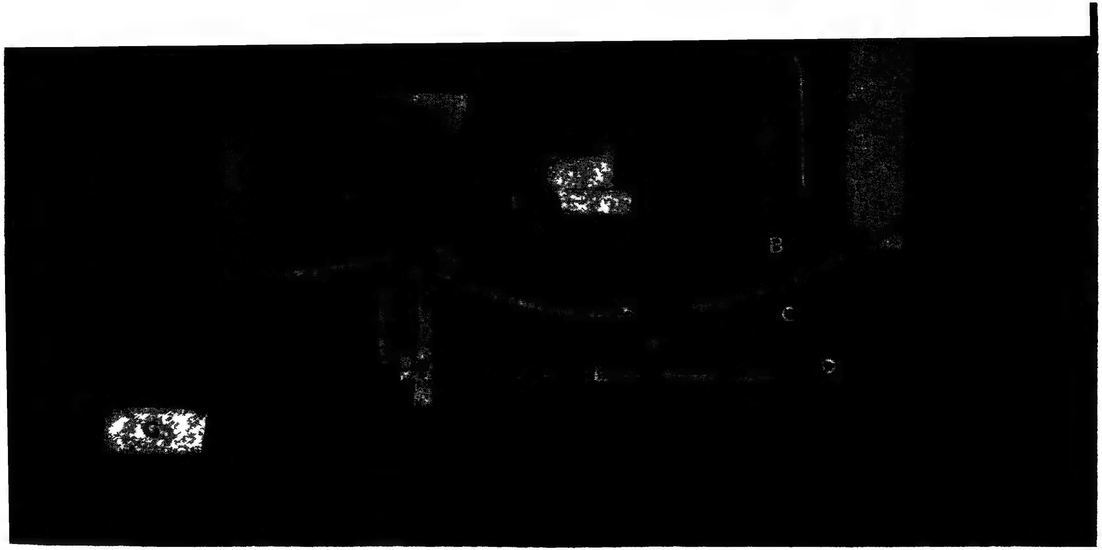


Fig. 32
CLEANING AND STRAIGHTENING MACHINE

The observation of simple facts of everyday existence is, very frequently, the factor by which their application results in methods enabling one to deal with problems of this character on a large scale.

If we take up any ordinary match box and slide out the "inner," we find that the matches contained in it can only set themselves in one direction, and that must be along their length, the box is too narrow to permit of any other arrangement.

It is on this principle that the straightening and cleaning machine is constructed, and, for the purpose of description, use can be made again of a figure shown on page 101.

The splints were left resting in the dryer and from this point they must be transferred quickly to the splint cleaner and straightener.

In properly equipped factories this transfer is done by means of a blower, otherwise a large amount of handling is necessary.

In the illustration it will be observed that a pipe A, dips into a hopper B, connected with a table divided down its total length by means of wooden strips.

The running of the machine can be explained as follows.

The hopper B, is open at the top and is provided with wooden bars running transversely across the bottom, and with sufficient distance between them to permit of the outfall's being regular and not too rapid.

As stated, B is fixed to the table marked C, and a rapid joggling motion is communicated to them both, with the aid of a crank motion, when the splints commence and continue to fall on to the grating of table C in a stream, until they arrive at the foot of the slippery slope, and are collected at D; during the passage the short splints and broken pieces fall on to the floor through the grating.

Coming back again to the match box illustration on

page 93, when it was stated that the matches could set themselves only in one direction, " C " can be described as a series of elongated match boxes, stretching from the hopper B to point D, the sides of these boxes being formed of thin wooden ribs, easily seen in the figure, compelling the multitude of splints to career only lengthwise from top to bottom, and to settle at the base all in the same direction.

Further observation will show a chain constructed of steel and running without stopping along a channel E at the foot of the table.

The chain is so constructed that it resembles a series of match boxes, so jointed as to enable it to pass over the various wheels as shown, so as continually to fill and empty itself as required.

At D the links of the chain are filled by the splints coming off the end of the table and falling into them, from which point they are carried forward to point F, where the chain takes a turn over, leaving the splints to accumulate and fall into the hopper G, which is detachable when full, and they are conveniently placed for the purpose of transferring them to the match-making machine.

CHAPTER VIII

CARDBOARD BOX MAKING

SLITTING machine—Inner box machine—Outer box machine.

THE preparation of cardboard, and the manufacture of that material into boxes, of which there are thousands of types, is somewhat beyond the scope of this work, but an account of the methods used to convert cardboard into boxes for the reception of matches, comes within our category.

Cardboard is made to the match maker's specification and can be of any colour and almost any thickness. For match boxes it varies from ·017 to ·022 in. thick, and for special purposes even up to ·125 in.

It is delivered in the shape of huge rolls measuring about 5 ft. long × 25 in. diameter, each roll weighing in the neighbourhood of 7 cwt.

To be in proper condition for box making, it should not be too dry, and is best with a content of about 8 per cent water, to prevent cracking of the board whenever it needs to be folded into the shape required.

Slitting into suitable widths is the first operation requiring attention, and a machine for this purpose, shown opposite, is requisitioned.

A is the roll of cardboard through which a spindle has been driven, the spindle being made fast with the aid of two cone-shaped cast-iron blocks.

The finishing edge, having been released, is conducted through the machine under and over rollers, for the purpose of tension and, lastly, under the circular cutters fixed on the spindles C.

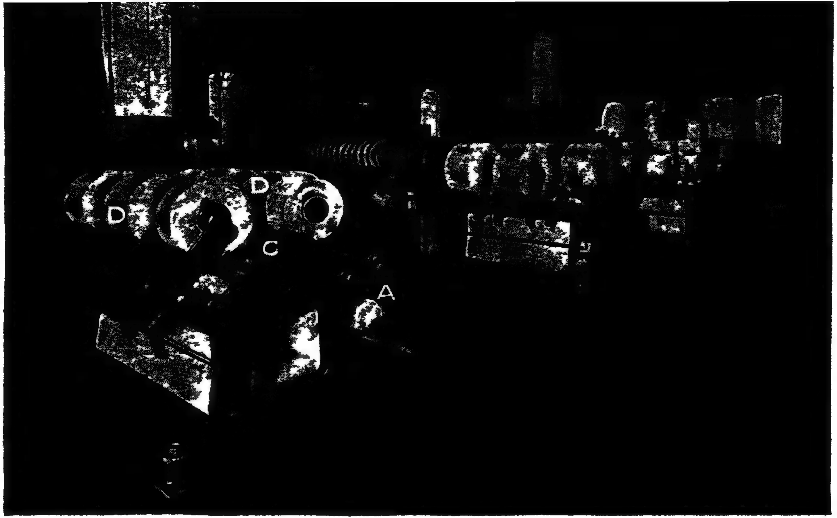


FIG. 33
SLITTING MACHINE

The cut reels are collected on the shafts D; this shaft is movable and from it the reels can be disconnected.

Whether cutting for "inners" or "outers," the procedure is the same. Any width of reel may be prepared, for it is only necessary to separate the circular cutters on shaft C farther apart or vice versa.

The reels having been prepared, the next step is the conversion of them into "inners," a machine for which is shown on page 107.

The reel out of which the inners are to be prepared is visible under the machine table at A, and for this identical purpose is cut 2½ ins. wide.

If the course of the reel is followed, it will be found being guided over pot B.

Pot B contains a solution of melted glue kept liquid by setting on a steam-heated plate. A lever C, to the end of which are attached fingers, is contrived to raise and lower itself at proper intervals in and out of the glue pot, which at each movement upwards communicates and leaves a dab of glue on the continually travelling cardboard, in such a place as to be convenient for the sticking of the box when folding occurs.

After receiving its dab, the strip of board travels upward in the direction of the arrow and actually through an orifice at D, at which point it is nicked at both ends to enable a fold to be effected. Still a little farther on it presents itself over a link in the chain E.

This link is the exact size and shape of the finished box in its outside measurements.

By means of a plunger H it is then forced into its resting place, viz. the link, and at the same moment receives a cut from a short knife, and the requisite length is detached to complete the task.

The piece of cardboard is now in the link of the chain and from this point travels over the pulleys K and F,

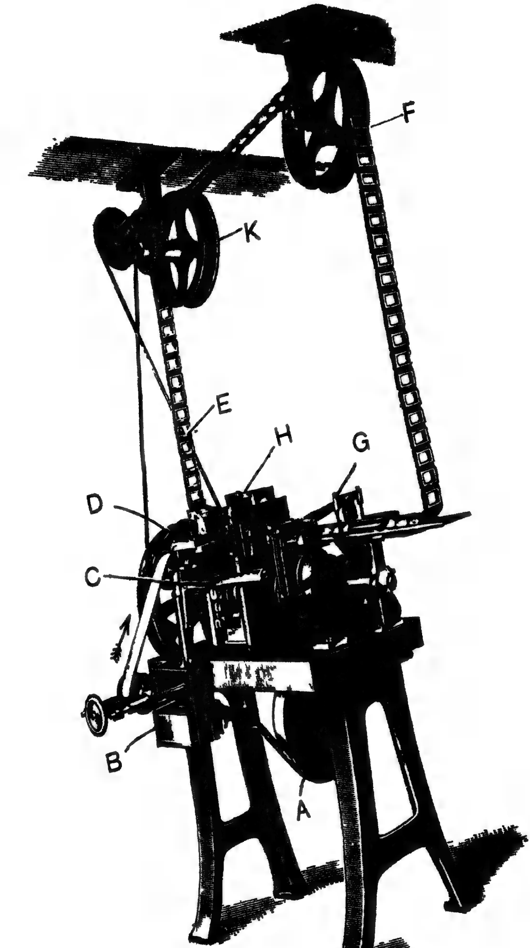


Fig. 34
INNER MACHINE

and finally down to plunger G, actuated from above downwards by the lever easily seen in the sketch, and is at the end of its career, being forced by the plunger out of the link as a finished "inner" into a convenient receiver.

In order to facilitate the comprehension of the method, the following diagram will serve—

10

11 12

Figures 1, 2, 3 and 4 point out the position of the glue dabs; 5, 6, 7 and 8 show the portions nicked out to allow for the operation of folding.

The small squares, 9, 10, 11 and 12 are by means of fingers, difficult to delineate, brought in front of the portions 1, 2, 3 and 4 where the glue is placed to receive them and to which they adhere.

The dotted lines show the folding points.

The object of carrying the chain moulded strips over the pulleys F and K is to allow time for the setting of the glue prior to ejectment of the product.

As there has been an absence of wet paste during the making, no drying cupboard is necessary, as is the case with the chip box, consequently, almost as soon as the chain arrives at plunger G, nothing further is required to prepare for the match machine.

However, this kind of box is by no means as strong

as its prototype, formed from the shaving and fixed together by means of paste and paper, but it serves its purpose and is more than strong enough to last out until the last match is used from the box, when it is always cast away.

The daily product of a machine turning out this class of box is 250 gross of " inners," and so easily is it manipulated that one girl can supervise the running of four and sometimes five machines.

The " outer " or cover for this type of box requires the use of a separate machine, but the preliminary steps are identical, viz. the slitting of the roll of board to the required width.

For the preparation of the wooden box, it is necessary to provide a printed label, but in the case of the cardboard " outer " the printed matter is on the strip itself, special printers being installed for this purpose, the process being conducted after the slitting of the large roll.

The " outer " forming machine takes the printed reel, cuts off the length of board to form the box cover, glues the edges where the laps come to hold it together, folds it over a mandril, similar to the principle adopted with the machine for making the wooden box, affixes the glue on to the one side for the reception of the sand friction and finally throws the loose sand, by means of a small revolving wheel, on to the adhesive provided, whilst the finished box is ejected, and is as in the former case of the cardboard " inner," almost ready for the match machine.

It will thus be seen that this is an occasion when the complete " outer " is turned out in one operation, and in this respect differs to that extent from the method adopted for the wooden-box " outer," where a separate and special machine is brought into use for the affixing of the sand-paper in small strips and for drying, and no provision of drying cupboards is wanted.

CHAPTER IX

PRINTING AND CASE MAKING

PRINTING would at first sight appear to be one of those things which are outside the purview of the manufacturer of matches.

Yet, to such an extent has development taken place, that in later years it has been found to be a profitable undertaking and a great amount of attention has consequently been bestowed upon it, and the application of a little thought will convince the amateur that the necessity has arisen for this to be taken in hand.

There is, firstly, the provision of the labels, covering the wooden box, and, in a factory boasting of any size of production, it is no mean figure.

An institution turning out 20,000 gross of boxes daily will require 2,880,000 labels for this purpose.

Secondly, there is the printing of the cardboard for the provision of the box made from this material, and lastly, the obligation of furnishing the requisite number of printed wrappers for the dozens and grosses.

Printing machines have, therefore, found a place in the manufacturers' curriculum, and occupy a special department devoted specifically to this object.

These machines are of the rotary type, each one of which is capable of putting out about 200,000 labels the day of 10 hours, and of giving an accuracy of cut, essential, when consideration is given to the fact that very intricate and accurate machines are employed in the production of the box.

The machines are made by Messrs. Chambon, whose engineering works are in London, although originally French.

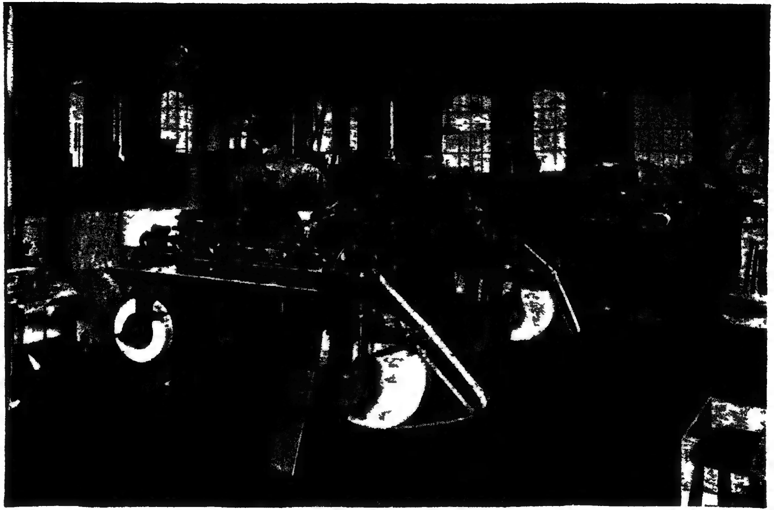


Fig. 35

CARDBOARD PRINTING AND RE-REELING

The method is the usual one of obtaining large rolls of paper, which are primarily submitted to the process of slitting into the width of reel required, by means of a machine similar in type to the one already described for performing the same operation on the cardboard.

The reel required for the printing of labels is slit into the correct width for three in a row.

By the multiplication of the wells for containing the ink, almost any number of colours can be printed at the same time, but consecutively. As a general rule match box labels are of one colour or, perhaps more accurately, of two, but the colour of the paper itself is one.

A passage of the reel of paper under the printing roller is the means of the application of the ink.

The cutting lengthwise to separate the three labels, and across to bring them into units, is effected by rotary and guillotine knives respectively, situated at the extreme end of the machine, at which point they accumulate in a holder and are conveniently bundled up for the box machine.

The printing of the cardboard is similarly done, but there is no cutting, the printed board being simply re-reeled, in which condition it is accepted by the box machine for this type.

The type of printing machine used for the above described purpose is shown on page 111.

Case making was also a thing with which the early match maker did not concern himself, although it is a necessary adjunct in the completion of all the operations.

When the industry was small, it did not profit the manufacturer to turn his attention to a subject which was more apparently the work of the case maker.

The more modern method is to tackle almost anything more or less incidental to the main purpose, and consequently the putting together of the cases has become an everyday operation in large establishments.

The parts of the cases exemplified by the words top, bottom and sides, are acquired from outside sources and completed by a machine holding the nails in a shaking container, from which position each separate nail is compelled to slide down its own shoot, point downwards, until it reaches a point where a hammer is provided for driving it home, and a dozen or more nails are at one and the same moment driven into the case, so that one stroke completes either the fixation of the top to the sides, or the sides to the bottom, thus enabling one man to complete 200 or even more cases per diem.

It can be said that case making is in its infancy, for it is more than probable that the complete turning out of these necessary articles will some time or other be done, from the sawing down of the tree itself to the final completion in every detail, and steps have already been taken, so that at some future date, the supply of the correct class of timber will be to hand, and Messrs. Bryant and May, Ltd., have already made arrangements, whereby a plentiful supply of home-grown stuff will be available, and the import of foreign timber will be, at any rate, for the specific requirements of match cases, dispensed with.

CHAPTER X

UP-TO-DATE MATCH MAKING

CONTINUOUS machines—Wrapping machine.

As the boxes and splints have now been assembled, and the detailed methods of their preparation have been explained, it is now time to describe the actual processes of the manufacture of the match, by means of the continuous and automatic machine.

As explained in a former chapter on the early methods, the remaining steps were all done separately, and in a piecemeal fashion.

These steps are: " Filling into frames," " Paraffining," " Dipping " into composition, and " Drying," and finally " Boxing." They were performed on entirely distinct machines for the purpose. To-day they are combined, and all of them effected on the same mechanical contrivance, and, from the moment the splints have been inserted into the chain, no further handling is necessary until after the dipped sticks are placed automatically into their box, consequently manual and oft-times laborious work has been eliminated, or has been reduced to a minimum.

Intelligent supervision of an interesting kind has superseded the older and crude methods; a result unpremeditated by the older manufacturers, and one which has given an opportunity for the payment of wages on a much improved and higher scale, a desideratum much to be desired.

The purpose of this chapter is then to detail, for the instruction of the reader, the intricacies and advantages accruing from this latest invention for dealing in huge

and almost inconceivable quantities with such a ridiculously small and obstinate piece of wood as a match splint, because superficially, nothing would be more difficult, but owing to the control of this almost miraculous contrivance, the process is made to appear excessively simple.

Its dimensions are such that, in some cases, special buildings have had to be erected for its reception.

Old factories were not built sufficiently strong to sustain its weight, which approaches 12 tons for a single machine, but the advantages to be derived from this mammoth were of such importance as to be fully equal to recompense, in the long run, any outlay incurred in this direction.

In addition to the saving of manual labour, there was the enormous saving of space realized by its introduction.

In large towns, where land is dear and floor space a consideration, it has been the means whereby, without exaggeration, double the number of matches can be turned out in the same room as formerly occupied.

There are many types of continuous machines, varying more or less in the details of their mechanism, but all principally the same.

Examples of two of these machines will be taken, of the first of which an illustration is provided, much in use on the continent of Europe and shown on page 117.

As can be seen, the machine is built of a solid cast-iron frame work and is supported on a bed of the same material.

It measures somewhat over 53 ft. long by about 10 ft. wide by 9 ft. high.

It is circulated by an endless chain, provided with innumerable apertures of a somewhat smaller diameter than that of a match splint.

The endless chain can be compared to a series of

frames from the obsolete frame filling machine, all strung together, and continually working round and round, without being compelled to detach them with the intention of paraffining, dipping, etc., and of attaching another when the first frame was complete.

The primary step in starting up is identical with the early frame filler.

The splints arriving in suitable ducts, direct from the cleaner and straightener, are fed into a reservoir at A, at the front lower portion of the machine, and are mechanically shaken and joggled into grooves situated at the base of the hopper, from which grooves they are propelled by means of specially contrived "pushers," working in line with the endless chain into their respective apertures, which seize and hold them firmly.

One row being filled the chain moves forward, and another one presents itself for the same operation, and so on continuously.

The direction of travel is depicted by the arrows, and from these pointers of the way it will be observed that, after the insertion of the splints, the latter are carried forward to a paraffin bath, kept at a constant level at B, and are dipped into the striking composition at C. From this point they continue through each storey of the machine and finally arrive at the top, where the matches are treated to the action of a fan and some heat, in order to facilitate their desiccation, and to render them in such a condition that they may be somewhat roughly handled whilst being inserted into the box without damage to the tip.

The journey now continues down the front and the completed product is finally forced out of the chain by means of a similar arrangement to the one by which they found entry.

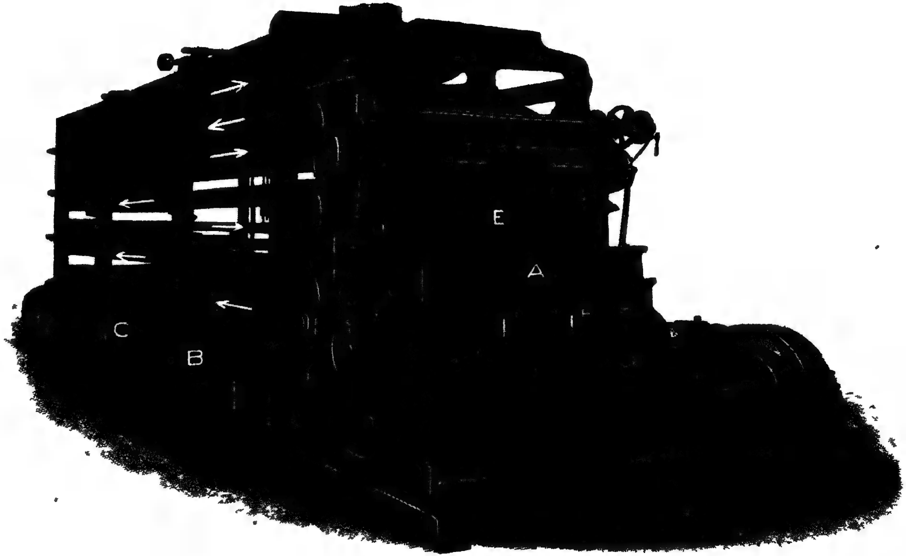


FIG 36
CONTINUOUS MATCH MACHINE

The dipping on this machine is somewhat novel and consists of a rising and falling plate, which becomes immersed in the composition and rises with the necessary supply, the surplus being levelled off by the aid of a gauge. This plate is pressed upwards against the paraffined splints, leaving behind sufficient composition to form the head, and the plate once more descends for a fresh supply of composition for those splints which are continually following in the wake.

As the matches emerge from the top and from under the blower, they descend to the collecting apparatus at E.

This collecting apparatus is semi-automatic and makes easy the removal of the completed match. The apparatus is constructed of steel receptacles, which pass in front of the machine in a continuous chain, the filled ones being removed on the left side of the machine and replaced by empty ones. From these receptacles they are transferred to larger hoppers by hand, so as to bring the matches into the state in which they are required for the box-filling machine, about to be described, with the assistance of another design shown opposite.

The output of the continuous match machine already described amounts to over 10,000,000 matches a day.

In this design it will be seen that there are two containers or hoppers, viz. the one at A in which the boxes to be filled are situated, and the other at B containing the complete matches.

The boxes are "nested," i.e. the "inner" has been inserted in the "outer," and, on starting the machine, four boxes at once are pushed out by plungers into the conveyor chain, built with the links and dividers sufficiently far apart to admit of one box, and the chain is moved intermittently forward to a point where the boxes are partially opened to admit the matches from B.

FIG 37
QUADRUPLE BOX-FILLING MACHINE

The bottom of the match container has a shaking motion, in order to bring the required number into a pocket, situated at the base of the hopper, to fill the box.

The boxes are then in front opened ready to receive their quantum, when they are passed on to another point, where they are automatically closed by a similar mechanism to that by which they were opened.

The full boxes issue from the apparatus on to a tray from which they are taken, to be painted, or in other words, to have the friction applied to the sides of the box.

More especially is this machine used for preparing safety matches, as the assembly of a large quantity of strike-anywhere matches in the match hopper is not a practical proposition, owing to the danger of fire, set up by the friction of the heads, when being forced into their final resting place.

Machines of the continuous type in use for the manipulation of the easily inflammable match, made to strike on any surface, are provided with a box-filler in front, and the matches are at once put into the boxes without a specially designed box-filling machine.

The crowning glory of the continuous match machine is, however, the one in use in most of the factories of Great Britain, and is the exclusive property of the largest firm of manufacturers, viz. Messrs. Bryant and May, Ltd., of Bow, London, E., Liverpool and elsewhere.

This machine is of such a size that a complete and full view showing all its parts is not practicable, and recourse will, therefore, be had to three, the first of which will be illustrated diagrammatically, on the opposite page.

The diagram shows a side view.

Although covering more ground space than the specimen machine already described, its total weight is considerably less, being built in a much neater and lighter manner.

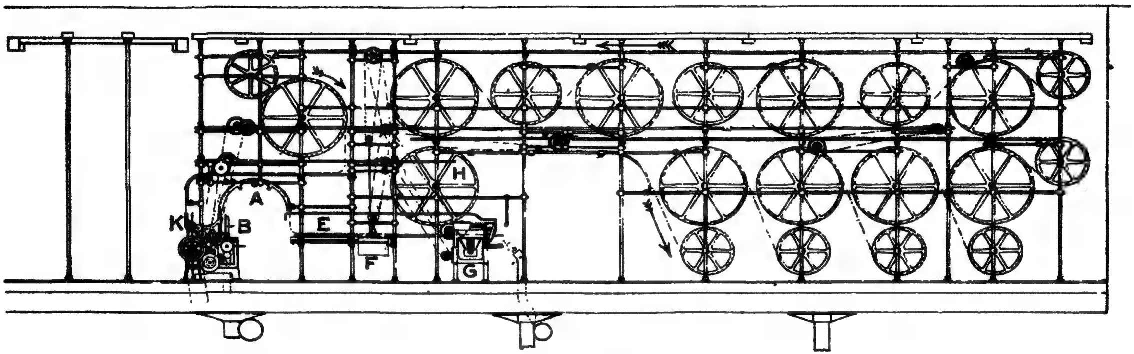


FIG. 38

BRITISH CONTINUOUS MATCH MACHINE

It requires no heavy bed plate and frame work, but is supported throughout on iron pipes screwed directly into the wooden floor.

The splints, neatly packed into ducts, are delivered to the splint feeder, who operates inside the arched space A, inserting them dexterously into the reservoir B. Situated at the base of B is a plate of 100 grooves, each groove easily admitting one splint, which is again joggled into position as described in the former machine.

The 100 grooves correspond with the 100 holes in the chain into which the splints are forced from the plate, and travel upwards at B and over the archway A.

The depth to which the splints are inserted is about $\frac{1}{8}$ in., or about the thickness of the chain itself, whilst the other portion extends downwards for paraffining and for dipping into composition.

After the journey over A, they travel on over E, which is a steam-heated plate, and from thence into paraffin bath F, constantly replenished with melted wax by a miniature bucket, dipping itself overhead in a well and being tilted over at a certain point of its elevation, so that its contents empty themselves into the bath and maintain it at a constant level, too great a depth being prevented by means of an overflow.

A little farther on at G, stands the dipping kettle, in which revolves a roller, furnished on its front side with a gauge, to ensure the provision of the requisite quantity of composition for a neat dip.

From this point the march of the ranks of dipped and paraffined splints is onwards over a second, somewhat more spacious archway, under which a constant supervision of the quality of the match being produced can be practised, and so on under and over each successive wheel until they finally arrive at the top track, travelling in the direction indicated by the arrows, until

they gain the position in the front of the machine at K, almost at the point from which they set out originally, at which time they are ejected into the box filler actually attached to the machine; but this will be described separately.

Front to back the total measurement is about 60 ft.

The total length of time during which the matches are in the chain in the process of drying is about one hour, and at the end of that period they are ready for boxing.

Matches in all degrees of dryness are, therefore, to be seen throughout the whole duration of the voyage round, some being quite wet, having just left the dipping roller, others half dry and finally in a condition to be packed into their ultimate resting place.

The output completely overshadows any other machine of this sort and amounts to no less than 7,200,000 matches per diem of 10 hours, or 1,000 gross of boxes, each one containing 50 matches, so that there are always 720,000 pieces inserted in the chain at once.

In the next figure is shown the front of the machine with the box-filling apparatus attached.

The matches can be observed just coming over the top and just prior to the final point of punching out.

This figure, reproduced from a photograph, will supplement and perhaps help to clarify the reader's conception of the whole machine better than the diagrams already depicted, about one-third portion of the whole having been pictured.

The reproduction shows the front of the apparatus where the filling of the splints into the hopper takes place, as well as the point at which they are ejected into that portion whose duty it is to insert the finished matches into the boxes. The final figure of the match

box-filling portion is shown and described in the succeeding lines.

As usual, at the rear of the endless band are a series of pins fixed into a steel bar, which move to and fro, working in a line and in time with the holes containing the matches and throwing them out into a chain formed

FIG. 39
FOREPART OF BRITISH CONTINUOUS MATCH MACHINE

into compartments and made sufficiently large to contain the exact number the box is calculated to receive. This chain we will call No. 1.

The boxes, having been fed into the shoot marked A, are carried forward in another and entirely separate chain, No. 2, which runs in juxtaposition with No. 1, so that each box, which has been half opened by means of a set of plungers, comes exactly opposite the link full of matches which it has to receive.

Another set of plungers, working through the links of No. 1 chain, forces the contents into the box situated in chain No. 2, containing the opened boxes.

At B, a special mechanism of plungers finally closes the now filled boxes and they are ejected and borne forward through a channel leading to the wrapping

FIG. 40

BOX-FILLER OF BRITISH CONTINUOUS MATCH MACHINE

machine. During the interval between leaving the match machine and before being wrapped, they are subjected to a close scrutiny and anything defective is thrown out.

It will thus be seen that from the moment the splints are fed into the container, until the packeting is complete, the operations comprised in " frame filling, " " paraffining," " dipping," " drying " and filling into boxes, are ceaseless and never ending.

As an example of applied mechanics, the modern match machine can hardly be surpassed, and, until its arrival, the number of employees necessary to get through the same quantity of work under the older system would probably amount to 100, whereas with this goliath they can be counted on the fingers and waste is reduced to a minimum.

Firing of the contents of the endless steel chain is very rare, as the point of absolute desiccation is never reached, but is only allowed to assume a condition, which allows of the insertion of the matches into the boxes without damage to the heads, and they finally dry and become hard in the boxes themselves.

In another form of machine, also in the possession of the same firm of British manufacturers, and one which is employed in the making of round or grooved sticks, the splints are not previously prepared, as has just been described in the two foregoing machines, but small blocks of pine wood cut to size, the depth of which blocks is the exact length of the splint required, are fed into the machine and forced into a cutting head, furnished with a series of small circular dies, working in a vertical direction upwards and downwards.

At the downward stroke the severance of the splints takes place and at the upward stroke they are inserted into the holes of the chain (similar in construction to all others) and are retained in that position, allowing the dies once more to descend and to cut a fresh row of splints, whilst the forward travel of the chain presents a fresh row of apertures ready for each upward stroke.

The other operations are an exact replica of those already described, with the exception that the filling into the boxes is only partly done.

The " inners " receive the matches and issue from the front on to a revolving table holding a quantity of covers

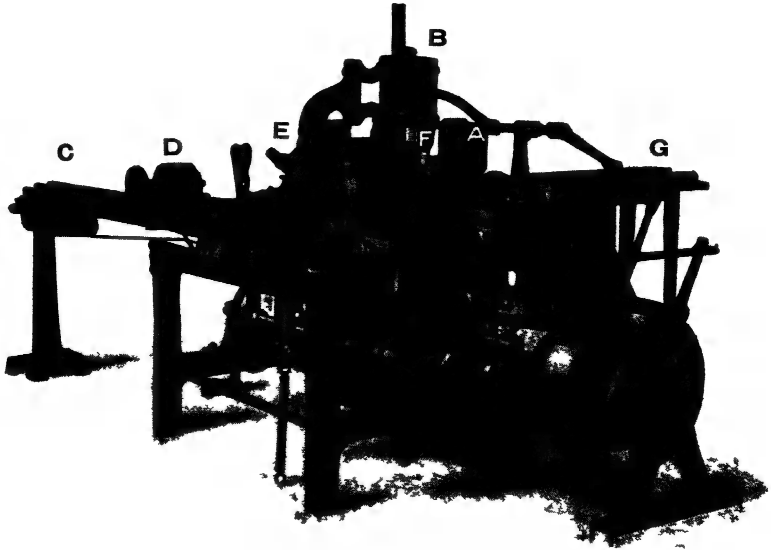


Fig 41
WRAPPING MACHINE

or " outers," round which are seated from 6 to 8 girls, whose work consists in sliding the one into the other, and are passed on to the wrapping machine. An illustration of this is shown on page 127.

The intricacies of this machine are such that it will be almost impossible to show the movements and from which point they emanate, and the reader will be compelled to take for granted a great deal.

The piece of paper, already cut to the size required and ready printed, is placed to a considerable thickness in a well underneath the paste pot A, arranged so that, by moving downwards, it can impart a streak of paste on the edge of the wrapping paper, where it is intended the fold shall come.

The paste employed consists chiefly of starch, to which a proportion of dextrine may have been added to increase its adhesive properties.

By means of fingers, which open and shut automatically, and are practically the same as those employed on the machine for preparing the box cover, the paper is drawn forward under B.

Cleavage of one sheet to another is provided against by adopting the principle of having the paper smooth on the printed side and rough on the opposite.

The boxes, which can be observed in the Channel C, are carried forward underneath a roller D, in order to level them up, in two rows.

On emerging from beneath the roller they are seized by fingers and lifted over, in tens or dozens at a time, on to the wrapping sheet of paper and laid down in the exact middle.

In the illustration ten boxes are being thus disposed of, *vide* E in the illustration.

The folding is now attended to by levers, acting from above and below, one of which can be seen at F.

The folded packet comes away from the machine at G, and is at once ready to be put into the case.

The daily out-turn amounts to 12,000 packets or 1,000 gross of match boxes, one girl attending to the feed and another taking away the completed packets and disposing of them in the cases provided for their reception.

CHAPTER XI

THE FACTORY AND ITS METHODS

AUTOMATIC fire extinguishers—Sprinkler system—Fire alarms.

As a great many of the details of the various machines have now been made familiar by which both "safety" and "strike-anywhere" matches are prepared, it will not be out of place if a mental picture of the factory at work is presented to the reader.

Needless to say, all factories are not constructed on the same plan, but, in the erection of a new one, the object aimed at is to make, as far as possible, the various processes dovetail one into the other, so that surplus labour in carrying and fetching is reduced to a minimum, and from beginning to end a continuous stream of the product, in many degrees of completion, is constantly and unremittingly being poured out.

The simplest and most approved plan for the purpose of arriving at this desideratum is to erect the building all on one level. Raw materials then enter at one end and the finished product makes its exit at the other.

Where space is plentiful and land is cheap, this method would be adopted, but in large manufacturing communities, where room is not available, recourse must be had to the opportunity afforded of making use of the air space, so that, under these circumstances, buildings of five or six storeys are provided, and the continuity is furnished with the employment of conveyors and lifts from one department to another.

This latter method is the one usually adopted in this

country and probably the most efficient one stands in the East End of London.

This factory occupies a site of about 5½ acres, the buildings themselves covering about 2 acres, and consists of basement, ground floor, and four other floors.

The yard space of 3½ acres is reserved for the storage of timber and is generally sufficiently large to be able to accommodate a year's supply, as the trees require to be felled in the fall of the year and shipped in the spring when the ice has disappeared round frozen Russia.

The logs, therefore, are stacked in the open and piled with powerful cranes to great heights, from where they are taken to the debarking and cross-cutting machines and saws, which are situated on the same level.

The first floor, which, if possible, is close and within easy contact with the railway siding, is reserved for the already cased up matches, ready for dispatch to any destination in or out of the United Kingdom.

Each floor above the other is supplying its quota for the completion of the match, firstly, working from below upwards and finally once downwards into the storeroom.

The second floor provides the splints and skillets and the third is occupied in completing the boxes.

The match machines situated in the topmost room, which is of loftier proportions than any of the others, are placed at a convenient distance apart, and resemble nothing more than a row of mammoth elephants in battle array.

Each machine is equipped with a fire-extinguishing hose, and the rapidity and ease with which fires—rarely occurring—on any part of its circular tour, are controlled and confined to a definite space, are due to the constant practice and acquired dexterity of the attendant who has charge of this item.

Throughout the whole of the building are installed overhead automatic sprinklers, on the fusible plug system, for the express purpose of coping with any conflagration which may happen during working hours, or at night.

The pressure in the pipes supplying water for this purpose is maintained by tanks at the summit of specially constructed towers, rising to considerable heights, the tanks being kept constantly full by automatic pumps, working slowly or quickly, in proportion to the amount of water being used through either the sprinklers or hydrants.

An additional precaution against any likely fire is furnished by means of pneumatic copper tubes running along all sections of the ceilings, any increased pressure in which, due to a rise in temperature, is at once communicated to the watchman in charge by the ringing of an electric bell, who, with the assistance of a diagram in his office, is apprised of the exact section where mischief is afoot, and, consequently, is in a position to tackle the problem before a flood of water has been let loose from the fusing of the sprinkler plug, sufficient in itself almost to employ the resources of a salvage corps.

The consumption of coal for power purposes is cut down to its lowest possible limits; all waste woods, sawdust, the bark of the logs, are consumed in a specially designed gas producer and are thereby converted into the energy required for the turning out of the insignificantly small but necessary match.

As a busy hive of workers, there can hardly be anything to compare with a match factory, as from start to finish there is the constant hum and click of machinery, the throb of which can be felt all over the building, the last echo of which does not disappear until one finally steps out into the open.

CHAPTER XII

STATISTICS AND LEGISLATION

PRICES of early light producers—Hyde Park Exhibition matches, 1851 and 1862—Paris Exhibition, 1867—Consumption of matches in Great Britain—Robert Lowe's first match tax, 1871—Prohibition of yellow phosphorus—Match taxes of 1916–1918—Conditions of employment

To return to the genesis of the industry and to make comparisons between the relative prices of some of the earliest specimens of light producers, as well as the consumption in the beginning, with that of the present day, is at one and the same time interesting and instructive.

The commonest type of tinder-box, constructed of tin, was usually sold at 1s., the piece of steel accompanying it for 4d., and the matches or preferably " spunks " for about 1s. a doz.

The price for the " spunks " was high enough, but it must be borne in mind that this was not the only drawback to their use, as the time occupied in obtaining one's desires was a factor not to be left out of consideration, for as a general rule three minutes was the time required to produce fire by this means.

The phosphoric taper, mentioned in our first chapter, was sold in small tin boxes for 2s. 6d.

The phosphoric bottle, also previously alluded to, cost 7s. 6d.

Dobereiner's lamp was sold for 1 guinea.

In *Bell's Monthly Compendium* for December, 1809, is found the following unique notification, given *in extenso*.

"INSTANTANEOUS LIGHT"

"Produced by the infallible German Fire Box, warranted to keep good any length of time, even in the coldest climate. Prepared by John Richards, chemist, 193 Strand, opposite St. Clement's Church.

"Officers in the army and navy, travellers, gentlemen in chambers and persons of every description, who want an instantaneous and frequent light, will immediately see the advantages of possessing this valuable preparation, which requires but a trial to convince them how eminently superior it is to every preparation intended to produce a similar effect.

"Directions for using are given on every box. Sold at 8s., 5s., 4s., and 3s. 6d. each box: where may be had the chalybeate aperient or true Cheltenham salts, in bottles at 2s. 6d., and a large and elegant assortment of family medicine chests kept ready for sale."

The *Observer* of 29th November, 1812, which by the way, was itself sold at this time at 6½d. a copy, has a further example of the almost prohibitive prices at which this class of fire producer was sold.

It is again embodied in an advertisement by Messrs. Accum and Garden, Chemists, 11 Old Compton Street, Soho. The advertisement is this time headed "fire-boxes, without phosphorus and sulphur," and no doubt, as in the previous case of John Richards, refers to the oxymuriate match, which, it will be remembered, was the method of getting a light by dipping a splint tipped with chlorate of potash, etc., into a sulphuric acid containing bottle.

Messrs. Accum and Garden's light producers were sold in boxes adapted for the pocket from 3s. 6d. to 5s. 6d. each.

In neither case is the number of matches stated, but that it cannot have been a great count can be accepted,

as according to some authorities 1s. for 100 was the price of the matches.

G. F. Watts, of 17 Strand, near Hungerford Market, brings us down to later times, as in his circular issued in 1834 he offers his " chlorate or lucifer matches " at 6d. a box, each box containing 100.

Evidently from his description, this match was an imitation of Walker, for he states that no acid is used in the preparation of his article, but describes it as follows—

" Being an important discovery for obtaining light through the agency of sandpaper only, and takes fire upon having an envelope of this paper rapidly passed over it, compressing the thumb and finger sufficiently without pinching it. This match is particularly adapted to pipe and cigar smokers, as the wood is so perfectly seasoned that it steadily burns till the whole is consumed."

In the same circular, Watts informs his customer that " he continues to make chemical matches and fire-boxes in all their usual varieties and that those ladies and gentlemen who have been accustomed to use chemical matches with bottles will find a plentiful assortment at his house."

The application of the use of yellow phosphorus seems to have been the fillip wanted to transfer the manufacture of matches out of the hands of the chemist and druggist into the care of the factory, and much light is thrown on the progress of the industry from the display of these goods at the great exhibition held in Hyde Park, in 1851.

At this exhibition various kinds of lights were shown.

Prominent amongst them were Peter Harrass's matches, sold at 2d. for 100. Untipped Saxony matches at about 1,400 for one farthing.

"Roasted wood" matches for quick ignition formed a part of the exhibit of Meyers of Mecklenburg.

Fürth of Shuttenhofen, in Bohemia, seems however, to have been the principal exhibitor with his dozen boxes with 80 lucifers, or "Congreves" in each, for one penny, also "ladies' lucifers" at about double that price.

These prices which are given from the *Practical Magazine* of 1871 were naturally eye-openers for English visitors and seem doubtful.

After the lapse of a further 11 years, and at the International Exhibition of 1862, it was found that most of the countries of Europe had commenced to manufacture on an extensive scale.

Sweden and Norway had initiated factories, as well as Belgium, France, England, Germany and Russia.

Sweden, Norway, Germany and Russia had the advantage of vast forests replete with suitable timber.

In the matter of quality, Austria must be presented with the palm of victory at this time, for it is reported that the chemical examiner in 1862 stated that Austrian matches were "distinguished above all others for excellence of quality and elegance of form, as well as for their ready inflammability, noiseless regular combustion, without scattering of the inflammable mass."

So far as cheapness was concerned, matches were shown by a Viennese maker at a price of ¼d. for 100, cases and boxes included.

At the Paris Exposition of 1867, there were again numerous varieties presented for inspection, amongst which were those of Messrs. Bryant and May, whose safety matches elicited from the examiner of this class the remark that they were entitled "to the thanks of the community."

Spacious and well equipped factories had by this time made their appearance in this country, notably those of Messrs. Dixon, of Newton Heath, near Manchester and Messrs. Bryant and May, Messrs. Hynam, Messrs. Bell and Black, in London.

Chief amongst the London firms was the first named, giving employment even at this period to over 1,000 hands in their factory at Bow, now of course demolished and a magnificent modern structure substituted.

At the present time factories exist in great numbers in most parts of the civilized inhabited globe.

In Great Britain there are twelve, most of them working with the newest type of machinery and finding employment in their buildings for probably over 7,000 employees.

In Ireland there are two.

The number in other countries can only be given approximately, and the following pre-war figures will, therefore, be accepted *cum grano salis*—

Russia, 49; Sweden, 10; Norway, 2; Germany, 75; Austria-Hungary, 10; France, 7; Belgium, 14; Japan is reported to have 150 factories, mostly of small dimensions, some of which, owing to depression, are now closed; China has 7.

For the year ending 31st March, 1921, the consumption of matches in England, Scotland, Wales and Ireland reached the enormous figure of 16,855,306 gross of boxes, each box containing 50 or 121,358,203,200 units, a large number of which were imported, as shown by the following statement—

Safety matches. Grosses of boxes of 50 matches each: Home-made, 2,617,130; Imported, 3,835,966; total, 6,453,096.

Giving a percentage of home-made safety, 40·55; and imported safety, 59·45; total 100·00.

Strike-anywhere. Grosses of boxes of 50 matches each.

Home made, 9,445,534; imported, 956,676; total, 10,402,210.

Giving the percentage of home made, 90·8; imported, 9·2; total, 100·0

Aggregating the two we find: Home made, 71·5; imported, 28·5; total, 100·0.

The estimated population for the year 1921 of the United Kingdom is 47,300,000, showing a consumption a head per annum of 52 boxes or 7¼ matches a head daily.

In order to present to the reader some idea of the vastness of the world's match industry, some figures based on the above consumption per capita will be useful.

If it is assumed that the population consists of 1,769,000,000 souls to whom the use of the modern match is known, and taking at a modest estimate 5 matches for each person daily as the consumption, then the total number of matches annually burnt would reach a total of 3,228,425,000,000 or 448,392,361 gross of boxes, each one containing 50.

The aspen or similar suitable wood required for the purpose would be 119,391,758 cubic feet.

Now, if we take by way of illustration an average aspen log of 15 in. diameter and 8 ft. long, the cubical contents of which would be about 10 ft., it then represents 11,939,175 aspen trees cut down and used up in the production of the modern convenient fire producer.

Again, if the trees were planted in 9 ft. centres, we should then have in the neighbourhood of 530 trees planted to an acre of land and should, for the use of the world, clear a space of 225,693 acres per annum.

Thirty years is a fair average age for an aspen plant to arrive at what may be described as match maturity,

therefore, to provide for a continuation of the industry on the present scale, without making any allowance for further increase, nearly 7,000,000 acres or 10,937 sq. miles of forest would have to be continually under cultivation.

The total weight of aspen would be 2¾ million tons.

Further, if the average length of an ordinary splint be taken as 1⅞ in., and we multiply the estimated world consumption, viz. 3,228,425,000,000, by this figure, we arrive at a total of 95,538,145 miles of single splints placed end on end, or, in other words, sufficient length to reach 3,980 times round the earth's circumference, or beyond the distance from the earth to the sun.

The possibility of disposing of this enormous number of matches almost staggers one's imagination and to reduce it to concrete figures will, perhaps, be another mode of bringing home to the reader the colossal nature of this almost universal industry.

Assuming, therefore, that 24 matches could be extracted from their boxes, struck and blown out in the minute by one person, it would occupy 3,000 people the space of 85 years to bring about the combustion of the above quantity.

Another method of presenting to the reader the extent of the industry is by the aid of the number of workpeople to whom it directly gives employment, without taking into consideration those whose work is subsidiary to the main object, and, assuming that most factories are now being worked with modern labour-saving machinery, an up-to-date establishment for all its operations, from the time the log is deposited for the debarking operation, until it has been finally transformed and delivered to the carrier for dispatch to the retailer, requires one hand for every 8 gross a day.

If we now make use again of the previous figure of 448,392,361 of the world's consumption, as stated

above, this would find employment for about 220,000 hands.

The export of matches from Great Britain and Ireland does not reach very large figures; formerly it was greater, as matches, mostly of the wax type, were dispatched in great quantities to our colonies, principally Australia and New Zealand, both of which places now manufacture their own under conditions which prevent the English manufacturer from being able to compete.

In the year 1922, the export figures were the following—

Safety matches. To foreign countries, 62,741 gross; to British possessions, 193,858 gross; making a total of 256,599 gross.

Strike-anywhere. To foreign countries, 25,110 gross; to British possessions, 112,303 gross; altogether, 137,413 gross.

Making a grand total of all grades of 394,012 gross, of a total value of £93,720, not a very imposing figure, and considering the number of foreign made matches imported into this country, the value of which on the same basis would reach the figure of £1,138,252, there would appear to be an opportunity for a considerable display of patriotism.

The industry from time to time has not been without its trials, apart from severe competition, to which almost continually it has been subjected.

It has attracted the cupidity of various Chancellors of the Exchequer.

There was the first attempt by Robert Lowe in 1871, and an account of the agitation and opposition this gave rise to, cannot be described better than by the writer in the *Practical Magazine*, issued in 1873. He says—

"On the 24th April, 1871, some hundreds of poorly clad and scantily fed working folk—women, boys and

girls—trudged wearily along from the eastern extremity of London to the sumptuous palace of Westminster.

"Their walk was a troubled one of several miles.

"A cordon of police barred their passage in the Mile End Road and compelled them to break up into detachments. Re-formed, they were again scattered at Whitechapel, and how they got to the Thames Embankment they did not well know.

"Something like a skirmish with the police took place near Westminster and the inscribed banners, carried by the wayfarers: 'We want to live,' 'Why should our industry be taxed?' 'What right have the government to ruin the match makers?' came to grief and there was an end of the procession."

This graphically described episode shows at least that, in spite of the circumstances in which the workpeople lived in those days, they were not lacking in spirit, and, although the agitation seemed a failure, it was not without its effect and the proposed tax, to which there was a considerable House of Commons and press opposition, was dropped, having lived for the space of one week only.

Robert Lowe anticipated that his yield from the taxed matches would bring into the exchequer a sum of money equal to £500,000 sterling annually, after allowing considerable margins for lessened consumption and fraudulent evasion.

His proposition was ½d. for 100 matches, whether made at home or imported, and he produced figures showing that the annual production in this country amounted to 605,000,000 boxes and that further 135,000,000 boxes were imported and 35,000,000 exported.

The Latin quotation which he made use of, viz. "Ex luce lucellum" (out of light a little profit) has become proverbial in the match trade.

The above figures, shown for the purpose of taxation, enable us to make comparisons between the consumption of to-day with that of the period under review.

At present the average contents of an ordinary-sized box amount to 50 matches. The above figures would consequently represent a consumption of 7·83 millions of gross, as compared with to-day's 16·85 millions; in other words, matches are used at double the rate they were in 1871.

In other directions as well the industry has not been free from legislative interference, as in 1906, by the international convention held at Berne, the use of yellow phosphorus was entirely prohibited.

Prior to 1906 and during the later years of the last century, regulations with respect to the use of yellow phosphorus had become so stringent, as to make it almost impossible to continue the making of strike-anywhere matches, and all factories where the use of the poisonous material continued were classed as "dangerous trades," and were subject to special rules with regard to ventilation, dentists, examination, etc.

To English match makers these rules were a serious drawback, as the great bulk of the non-safety matches were manufactured by them and formed by far the largest proportion of their business. Luckily for them, however, their continued existence was preserved by the substitution of the sesqui-sulphide of phosphorus already described.

During the Great War, new ways for producing revenue for its continuance were introduced and matches had to shoulder some of the burden. An excise and import duty amounting to 3s. 4d. for 10,000 matches was made law and this time there was no opposition, the manufacturers and workpeople agreeing without demur to the imposition.

Two years later in 1918, this tax was increased to 5s. for 10,000, at which figure it remains to the present day, and yields a sum of over £3,000,000 per annum.

It is often asked why the cost of this necessary everyday article has so increased during the last few years, the answer to a large extent is supplied from the above facts, as the duty itself is responsible for nearly 4d. a dozen boxes, a price at which in former times matches could be purchased.

Other factors have naturally contributed, such as the enormously increased cost of the raw materials, transport and wages, the last named being nearly three times as high as prior to the war.

Aspen, for example, which may be described as the basis of the industry, now costs nearly three times the price at which in former days and before the late turmoil it could be purchased, and so on throughout the whole of the other materials.

In the year 1912, the total value of the materials used was £427,281, whereas at the moment a computation of over £800,000 would not be excessive.

Competition from abroad has always been severe, and, whilst it is not the intention of the author to digress into the polemics of any economical controversy, a word may not be out of season, to the effect that, at the present moment, match making, in consequence of the rate of exchange in foreign countries, is being subjected to a rivalry to which it has hardly ever been exposed before, and matches coming from such distant countries as Esthonia and Czecho-Slovakia are being offered for sale in the English market.

It is, therefore, to their credit that English manufacturers have been for years past, and even now are able to hold their own under these difficult conditions and, further, have coupled with this success an immense

improvement in working conditions, in increased wages to the operatives, and a greatly enhanced standard of comfort, and of life, in spite of the fact that the manufacture is always at a disadvantage with foreigners, who have an ample supply of the necessary timber always at their door, whereas, practically all raw material must be imported into this country.

In the early years of the present century, wages were anything but good. A woman's wage was about 2½d. an hour, a man's 4½d. Nowadays the former earns at the rate of 9¼d., whilst the latter obtains 1s. 4¼d.

Hours of employment have been shortened from 60 hours a week to 47.

Again, the transformation from badly ventilated rooms to the clean and healthy surroundings of the up-to-date factory, built from its foundations on hygienic lines, is nothing short of a miracle.

Match making has perhaps, above all other industries, kept pace with modern inventive genius.

In Great Britain and America, through the instrumentality of progressive and broadminded directors, the lot of the worker, whose welfare from the point of view of wages and other material, as well as social benefits, has been wonderfully improved, is made happier.

Welfare workers are assiduous in their attention to all that concerns the moral, mental and physical happiness of almost every member of the match community.

A certificated nurse is constantly in attendance to administer immediate assistance and first-aid to accidents, or any cases of sickness that may occur.

A qualified doctor attends daily to examine and advise and prescribe for any cases beyond the range of the matron.

The match makers of this country were amongst the first, if not actually the first, to install Whitley councils,

at which meetings sit both masters and men, and they have been found extremely useful in settling, in their incipient stages, those natural divergencies of opinion, and of preventing them from assuming proportions so often leading to greater difficulties.

Dining rooms and immense kitchens where cheap and wholesome food can be obtained at prices very much below the actual cost have been installed.

The match operative is now participating in the profits of the work in which he spends his energy and life, as also in a non-contributory insurance scheme especially created for his benefit.

Funds have been set aside to provide supplementary " out of work " pay in the event of slackness occurring, so that the lot of the " match under-dog " is at least to be envied, as everything possible is done to relieve the monotony of work and to endeavour to convince the worker that the grinding out of a profit for the benefit of the shareholder is not the " be all and end all " of modern joint stock companies.

It may, therefore, be stated fearlessly that the employee in a British match factory is amongst the most contented of any similar undertaking to be found anywhere, and that match making, providing as it does a healthy, clean and remunerative occupation, is a thing to be fostered and preserved.

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